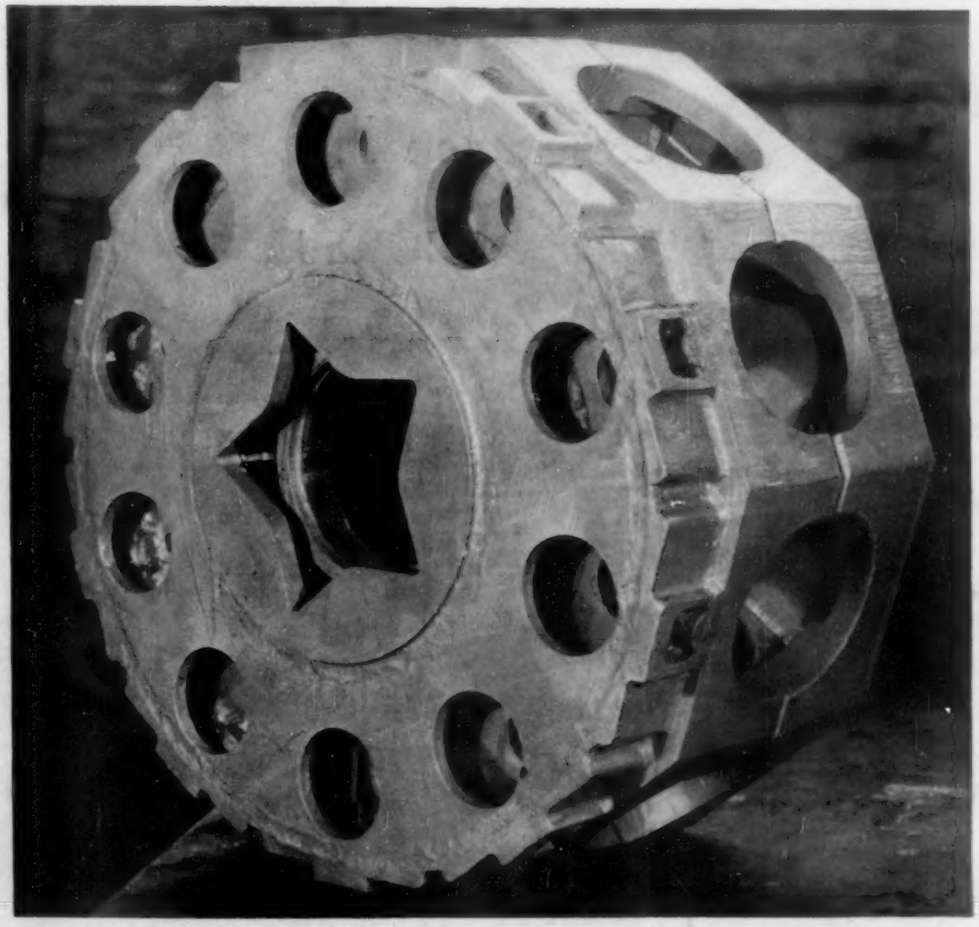
East Engin.
Library

FEB 20 1936

THE AMERICAN WELDING SOCIETY JOURNAL

VOLUME 15 FEBRUARY 1936 NUMBER 2



PUBLISHED MONTHLY FOR THE ADVANCEMENT
OF THE SCIENCE AND ART OF WELDING

FALL MEETING

AMERICAN WELDING SOCIETY

CLEVELAND

October 19 to 23, 1936

IN CONJUNCTION WITH

METAL CONGRESS EXPOSITION

Every indication points to one of the most interesting technical sessions ever held by the Society and an unusually successful Metal Exposition including welding exhibits.

THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 15 | NO. 2

FEBRUARY

Contents

Technical Papers, Items and Reports

	Page
One of the Welded Steel Crankcases Built by Lukenweld, Inc., with Low Alloy High Tensile Cromansil Steel	Frontispiece
Advantages of Welding in Continuous Structures, by *Inge Lyse*	2
Nitrogen in Metallic Arc Weld Metal, by *Dr. John W. Miller*	5
Assembling the New Steel Radio Tube by Electrical Resistance Welding, by *M. L. Eckman*	10
Composition of Electrode Coatings, by *C. J. Holslag*	12
The Phenomenon of the Erratic (Unstable) Welding Arc, by *G. M. Tichodeev*	13
Arc Welding Used in Framing Large Residence, by *W. T. Cook*	17
Bending Brakes and Bulldozers Bettered by Welded Construction, by *Merritt L. Smith*	18
Continental Radial Diesel Engines Use Light-Weight Welded Crankcases and Bases, by *George M. Gillen*	19
Pipe Lines Cross Highway, by *A. F. Davis*	20
Cutting Structural Steel, by *J. H. Zimmerman*	21
Current Welding Literature	26

Society and Related Activities

Engineering Foundation Research Committee	27
Pamphlets	27
Welding in Europe	27
A. S. T. M. Meeting	27
Welding Interests Other Organizations	27
Translations	27
Civil Service Examinations	28
Correction in Article "Prediction of Weld Performance"	28
Specification for Carbide of Calcium	28
Urges Wider Use of Steel Construction for Permanent Dams	28
Section Activities	28

ISSUED MONTHLY

AMERICAN WELDING SOCIETY

PUBLICATION OFFICE
20th and Northampton Sts.,
Easton, Pa.

EDITORIAL AND GENERAL OFFICES
33 West 39th St.,
New York, N. Y.

OFFICERS FOR 1935–36

President: J. J. Crowe
Treasurer: C. A. McCune
Senior Vice-President: E. R. Fish
Secretary: M. M. Kelly

Divisional Vice-Presidents
A. G. Leake, New York & New England
T. C. Smith, Pacific Coast
W. W. Reddie, Middle Eastern
C. L. Eksergian, Middle Western
E. E. Dillman, Southern Division

SECTION HEADQUARTERS

PHILADELPHIA
Engineers' Club, 1317 Spruce St.
CHICAGO
608 South Dearborn St.
PITTSBURGH
Room 906, House Building
NEW YORK
33 West Thirty-Ninth St.
NORTHERN NEW YORK
General Electric Co., Schenectady, N. Y.
CLEVELAND
410 Hanna Building
SAN FRANCISCO
Park Ave. & Halleck St., Emeryville, Cal.
LOS ANGELES
2423 East 58th Street
BOSTON
Engineering Societies of New England
715 Tremont Temple
WESTERN NEW YORK
500 Morgan Bldg., Buffalo, N. Y.
DETROIT
Paramount Welding Supply Co.
5950 Second Blvd.
PORTLAND, ORE.
P. O. Box 1899, Station F
MARYLAND
516 N. Charles Street
MILWAUKEE, WIS.
2841 N. 51st Street

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Copyright, 1936, by the American Welding Society

Subscription $4.00 per year in United States and possessions; $4.50 in Canada, Foreign Countries, $5.50.

Entered as second-class matter January 15, 1932, at the post-office at Easton, Pa., under the Act of March 3, 1879.

Advantages of Welding in Continuous Structures*

By INGE LYSE†

Introduction

In structural design we have in general two major problems to consider, that is, the use of free or of continuous connections. By continuous connections is meant all connections capable of carrying a certain amount of bending moment. The question of continuous structures *vs.* simple connections has recently been brought forcefully to the fore by the reinforced concrete industry. In discussing this question before the 1935 annual convention of the American Concrete Institute, Mr. Mehren, President of the Portland Cement Associated, stated:** "Almost to this day, in the United States at least, the assembly (that is, of the structural members) has followed designs traditional in timber and steel. Each element is considered independent of others—the post and lintel system merely applied to a new material. The great inherent advantage of concrete, that which makes it different from all other structural materials, which enables it to be adapted to any architectural form, which gives to it tremendous advantages in economy—that characteristic, continuity, has been neglected." This statement applies equally well to welded structures. We have the same opportunities for adopting welded structural steel to any architectural form, we have the same advantages of rigidity and continuity. Have we fully realized these facts? Have we departed from the conventional types of joints which were specially adapted to riveting and developed the types of connections in which the full advantage of welding is utilized? Unfortunately, we have not as yet realized the full advantage of structural welding. In meeting the challenge of the reinforced concrete construction the structural steel industry should and must give closer attention to the advantage of welding individual members into a rigid unit. It is with the purpose of stimulating the interest in all welded connections in structural design that this paper is being presented.

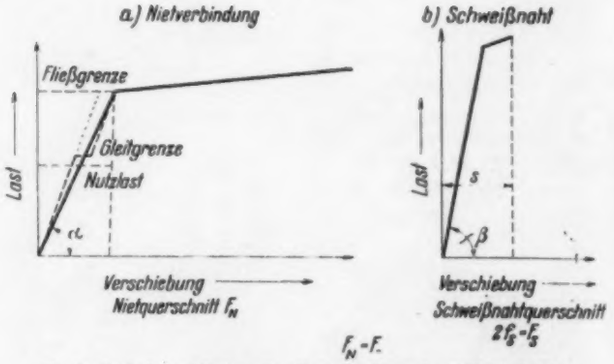


Fig. 2—Typical Load-Deformation Curves for Riveted and Welded Joints

* Paper presented before Fall Meeting, AMERICAN WELDING SOCIETY, week of September 30, 1935, in Chicago. Report contributed to the Fundamental Research Committee of A. B. W.

† Research Associate Professor of Engineering Materials, Lehigh University, Bethlehem, Pennsylvania.

** "Concrete—Yesterday, Today and Tomorrow," by Edward J. Mehren, Proceedings of the American Concrete Institute, Vol. XXXI, 1935.

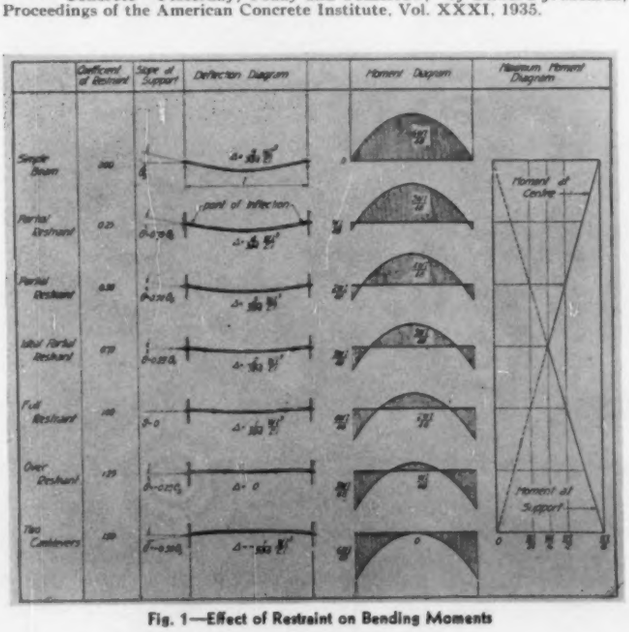


Fig. 1—Effect of Restraint on Bending Moments

Rigidity of Welded and Riveted Connections

Although we generally consider riveted connections as being free or unrestrained, this is actually not so. A considerable amount of rigidity may be produced by the rivets, but because of the many uncertainties which enter any riveted connection it would probably be inadvisable for designers to take rigidity of riveted connections much into account. With welded connections, however, we have comparatively little difficulty in producing an appreciable amount of rigidity, and we can readily carry the welded connection toward a fully rigid joint. In order to review some of the fundamental relationships between free and rigid connections I will present a diametrical sketch of the effect of restraint on the bending moments. Figure 1 is taken directly from the valuable paper, "The Relative Rigidity of Welded and Riveted Connections," by C. R. Young and K. B. Jackson of the University of Toronto, and it illustrates very clearly how even a relatively small coefficient of restraint reduces the bending moment appreciably. Making use

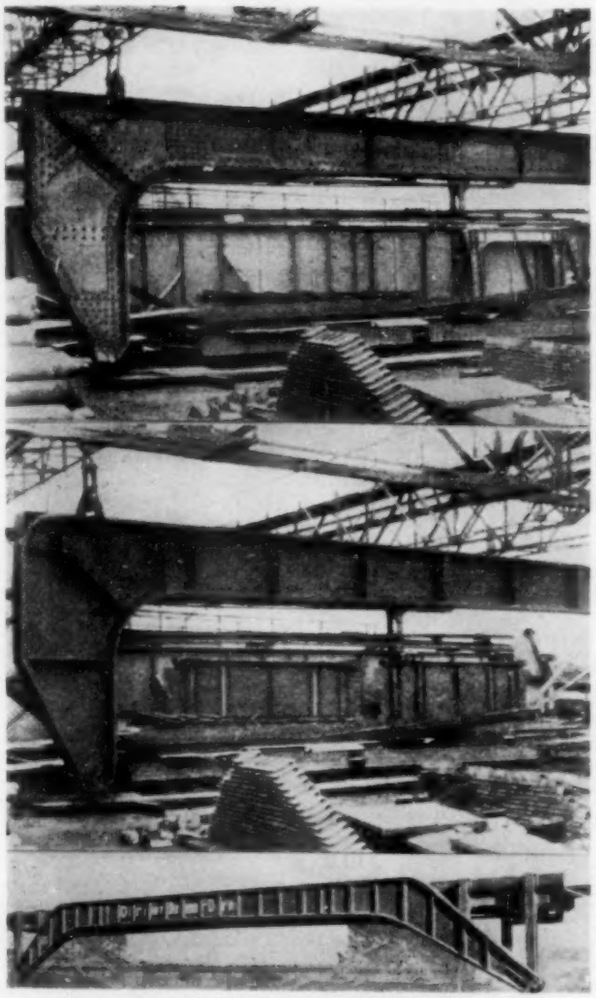


Fig. 3 (Top)—Riveted Frame Used in the Past

Fig. 4 (Center)—Welded Frame Used at Present

Fig. 5 (Bottom)—Welded Frame of 72-Ft. Span

of this restraint in design will result in a considerable economy in the final structure. The problem facing the structural steel engineer is therefore that of ascertaining how much restraint or rigidity may be counted upon in welded connections. Although we have some information available on the amount of rigidity in certain types of connections, the field is far from explored and much experimental work has to be done before we can take

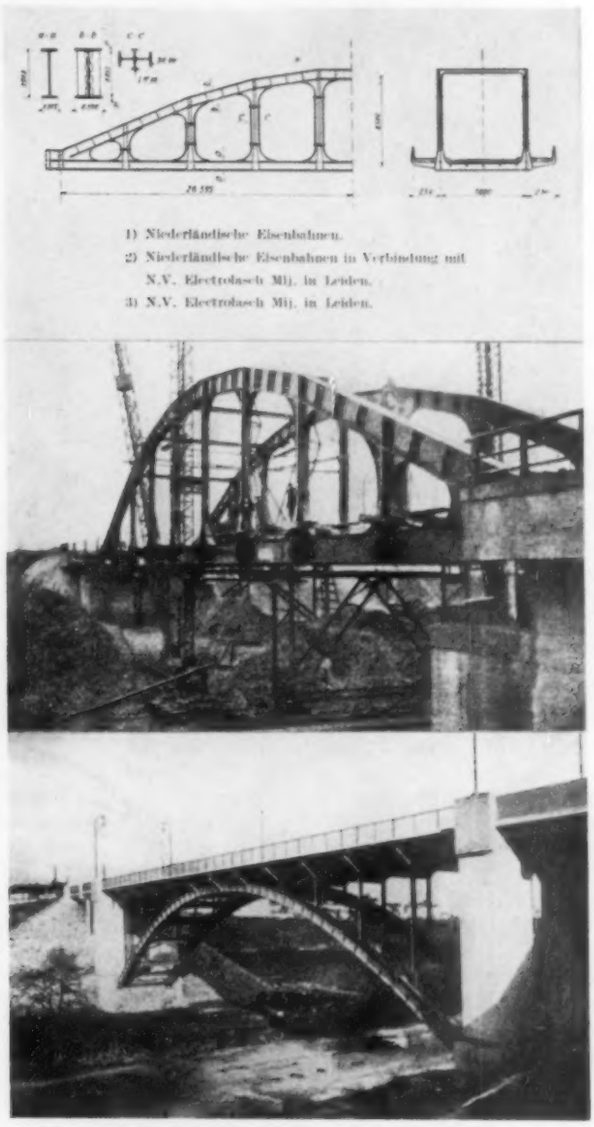

1) Niederländische Eisenbahnen.
2) Niederländische Eisenbahnen in Verbindung mit N.V. Electrolasch Mij. in Leiden.
3) N.V. Electrolasch Mij. in Leiden.

Fig. 7 (Top)—All Welded Vierendeel Bridge

Fig. 8 (Center)—Photograph of the Vierendeel Bridge

Fig. 9 (Bottom)—German All Welded Two-Hinged Arch Bridge

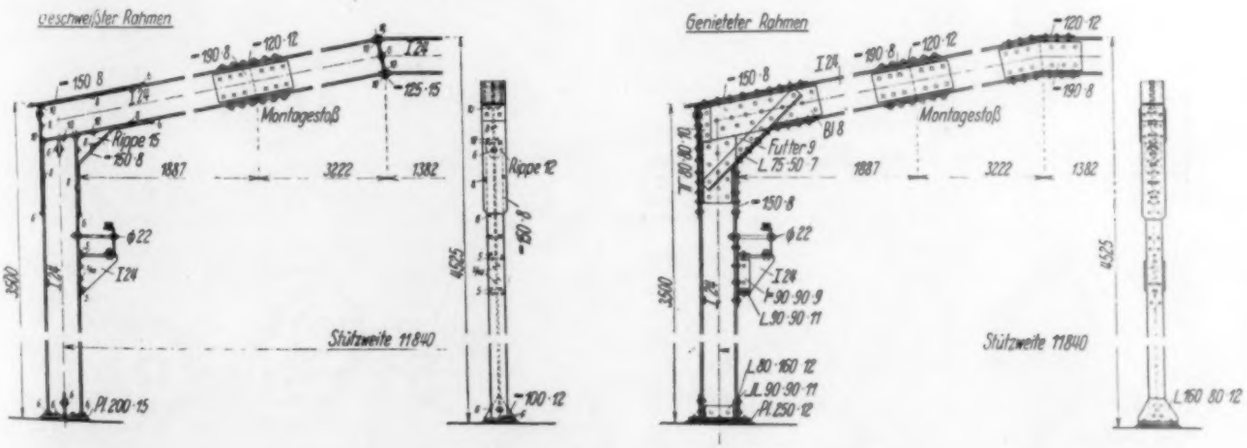


Fig. 6—Riveted and Welded Frames for Industrial Buildings

Fig. 10—Details of Welded Hinge

the full advantage of the rigidity in welded structures. I am not going to discuss the relative rigidities of welded and riveted connections. However, I will give you a picture of the general conditions as revealed by the load-deformation behavior. In Fig. 2, which is taken from the paper, "Über das Zusammenwirken von Nietverbindung und Schweissnaht," by H. Kayer and A. Herzog of the Technical Institute of Darmstaft (*Der Stahlbau*, July 20, 1934, page 113), the diagram to the left represents a riveted connection and that to the right a welded connection. The greater deformation in the riveted connection is so apparent and the effect of the slip between plate and rivet so well illustrated that further comments are superfluous.

Recent Developments in Foreign Countries

It seems that European engineers are more aware of the economic advantages in welded structures than we are. I will therefore present some typical foreign designs.

Figures 3 and 4 show, respectively, a former riveted rigid frame as used by the German Government Railroad and the new welded frames which replaced the former. The simplicity of construction and the pleasing appearance of the welded construction make it apparent why the change was made. Furthermore a 25 per cent reduction in material and a similar reduction in cost present an excellent illustration of what economies welding may give to structural design. Another type of welded frame used by the German Railroad is shown in Fig. 5. This frame had a span of 72 feet. The forthcoming government work on grade crossing elimination may be an excellent field for the use of all welded rigid frame bridge construction.

An illustration of the type of welded frame which replaces riveted connections in industrial buildings is shown in Fig. 6. The simplicity of the welded frame to the left as compared to the riveted frame at the right is apparent and the economies obtained by changing to the welded construction was as much as 25 per cent also for this case. The span was about 39 feet. The renewed interest in the Vierendeel type of bridges created by the introduction of all welded connection is especially significant. A number of welded Vierendeel bridges have been constructed in Europe during recent years because of their economical advantage. Figures 7 and 8 show a bridge which was constructed last year in Holland.

Another type of bridge in which welding is being used extensively is two-hinged arch bridges. Because they are closely related to the more apparent continuous types of bridges I will mention a few of them.

An all welded arch bridge of 166-foot span is shown in Fig. 9. A detail of the hinge is shown in Fig. 10. This is a German construction and the reduction in weight over a riveted construction was 22 per cent. Another all welded arch bridge is shown in Fig. 11. This bridge was constructed in Sweden and has an arch span of 184 feet. It was originally designed for riveted connections, but redesign for welding showed that a 40 per cent reduction in weight and about 25 per cent reduction in cost would result. A unique type of rolled flange section which is used extensively in Swedish bridge construction is shown in Fig. 12. This type is very convenient for the welding of girders of all kinds.

These few illustrations show that the field for structural welding is as yet far from fully developed.

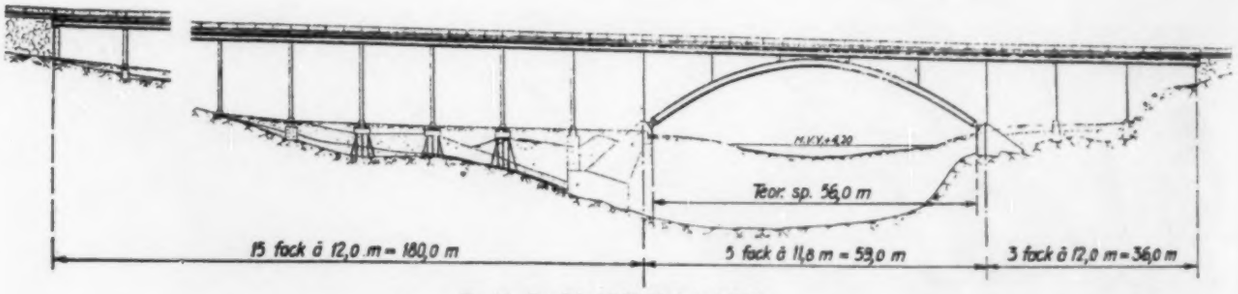


Fig. 11—Swedish All Welded Arch Bridge

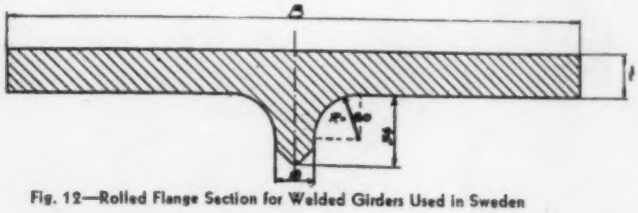


Fig. 12—Rolled Flange Section for Welded Girders Used in Sweden

Nitrogen in Metallic Arc Weld Metal*

By DR. JOHN W. MILLER†

Acknowledgment

THE author wishes to express his most sincere appreciation to "The Engineering Foundation" and the "American Institute of Electrical Engineers," through whose financial assistance this investigation was made possible.

To the members of the instructing staff at the Massachusetts Institute of Technology for their cooperation and assistance during the investigation.

Introduction

In recent years, the process of electric arc welding has made very remarkable strides and has gained an important foothold in various industrial fields. A great deal of attention is now being given to the physical testing of metal deposited by the electric arc and considerable research has been, and is still being done, to improve the quality of the deposited weld metal.

One of the most important problems with which the welding engineer is confronted is the control of the nitrogen content in the deposited weld metal. A number of investigators have worked on this subject but no one of them has endeavored to cover the entire field. For the most part, the work has been concentrated upon the effect of the nitrogen in the deposited weld metal and not upon the actual control of the nitrogen content.

The Occurrence of Nitrides in Weld Metal

In weld metal, iron nitride occurs most frequently as needles, together with colorless, structureless areas, and Braunite. A large number of people are of the opinion that the needles which we observe, may, in reality, be cross sections of plates occurring in the metal. It is sometimes found that there is present in the weld metal, a colorless, structureless constituent. It may be that these colorless, structureless areas are due to the rate of cooling of the weld metal. At the welding temperature, and during part of the cooling, the iron nitrides are dissolved in the austenite and upon the transformation to alpha iron, iron nitrides tend to precipitate in the form of needles but due to the rate of cooling, the segregation is incomplete and the result is areas of ferrite which are rich in nitrides of iron. This might be termed a "secondary" ferrite.

A phenomenon similar to this has been noticed in low carbon steels in which the segregation, or complete separation of the iron carbide, has been inhibited (between the Ar_1 and Ar_3) by the cooling rate and a "secondary" ferrite formed. This material is also a colorless, structureless constituent which has definite lines, or boundaries of demarcation.

It was also noted that the nitride needles sometimes segregated and that they might be precipitated at both the grain boundaries and within the grain itself. In some instances, widened grain boundaries were evident.

In attempting to eliminate the formation of iron nitride, various coatings have been devised for protecting the electrode, arc and crater metal. These coatings have, to a certain extent, been successful but certain types are far more efficacious than others.

X-Ray Diffraction Investigation of Weld Metal

At the outset of the investigation, it was hoped that an X-ray diffraction investigation would give some proof of the composition and structure of the needles appearing in the weld metal. For this investigation, a Phragmen camera of the Seemann-Bohlin type was chosen. A chromium target was employed.

The chemical analysis of the weld metal investigated was:

C	0.016
Mn	0.016
P	0.009
S	0.018
Si	0.008
N	0.127

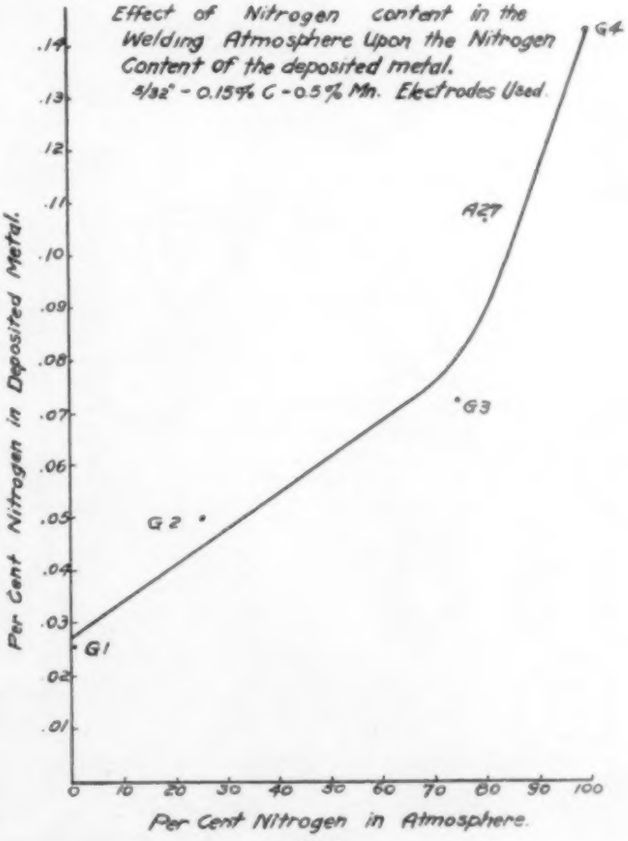


Fig. 1

* An abridgment of thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Science in Metallurgy, Massachusetts Institute of Technology. Presented at Fall Meeting, A. W. S., week of September 30, 1935, in Chicago.

† Metallurgist, Reid-Avery Company.

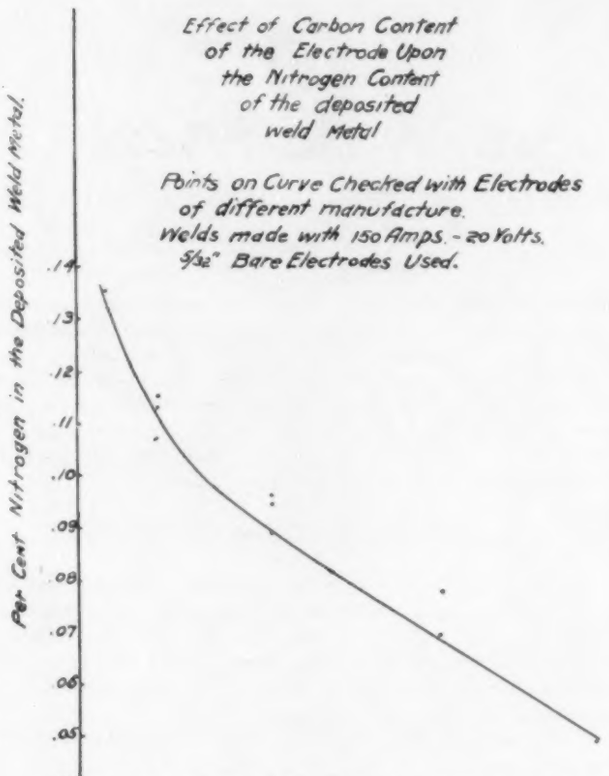

Effect of Carbon Content of the Electrode Upon the Nitrogen Content of the deposited weld Metal
Points on Curve Checked with Electrodes of different manufacture.
Welds made with 150 Amps. - 20 Volts.
5/32" Bare Electrodes Used.
Per Cent Nitrogen in the Deposited Weld Metal.
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
Per Cent Carbon in Electrode.

Fig. 2

A diffraction pattern of this sample showed not only the lines due to alpha iron but also some strange lines. Upon measuring the film and comparing the $\sin^2\theta$ values of the strange lines with those values obtained by Hägg in his work on the iron–nitrogen system,[49] it was found that two of the strange lines were identical with those values obtained by Hägg for the gamma prime phase of the iron–nitrogen system. The weak lines in the case of the weld metal corresponding to the very strong lines of the gamma prime phase of the iron–nitrogen system.

In order to more definitely establish as to whether or not these lines were due to the gamma prime phase of the iron–nitrogen system being present, a sample of the weld metal filings were sealed in an evacuated combustion tube and heated to 1150° Fahrenheit for fifteen minutes after which the tube was broken in a carbon dioxide ice–carbon tetrachloride mixture which gave a quenching temperature of −19.5° Centigrade. This was done in order to retain the iron nitride in the form of solid solution in the alpha iron.

The diffraction pattern of this sample showed some of the strange lines, the only difference being in the lines which were due to the gamma prime phase of the iron–nitrogen system. The stronger of the two gamma prime lines of the annealed sample showed very weakly in the quenched sample, the weaker line not showing at all. This would indicate that either the sample was not quenched with sufficient rapidity to retain the iron nitride in the form of solid solution, or that there had been some precipitation of the iron nitride during the three-hour exposure of the X-ray camera. The latter explanation seems, to the author, to be the more logical. Hensel and Larsen[38] reported considerable aging to have taken place in a very few hours at room temperature.

Upon a microsopic examination of annealed and quenched samples of the same weld, it was found that the needles were present in large quantities in an annealed sample but were absent in a quenched sample. This, considered with the X-ray diffraction results, proves that the needles in weld metal are probably the gamma prime phase of the iron–nitrogen system and correspond to the compound Fe_4N.

Eight strange lines, other than those belonging to the iron–nitrogen system, were present in the diffraction pattern which were not accounted for. These eight lines were present in both the annealed and quenched samples with equal intensity. Upon microscopic examination of unetched samples in both the annealed and quenched conditions, it was found that considerable impurities were present in the metal. It was the opinion of the author that these lines were probably due to oxide impurities and for that reason, samples of ferrous-, ferric- and ferrous-ferric oxides were investigated and diffraction patterns obtained. Four of the strange lines corresponded to the stronger lines obtained in the diffraction pattern of the ferrous-ferric oxide. This showed that these four lines were due to the presence of the magnetic oxide in the weld metal.

The four strange lines which were unaccounted for were probably silicates or complex oxides. They were, however, present in the same intensity in the pattern, regardless of the heat treatment which the sample received.

Due to the fact that the needles were the only constituent to disappear upon heat treatment by quenching and due to the fact that the two lines of the gamma prime phase of the iron–nitrogen system were the only ones effected by heat treatment, it would tend to prove that the needles were probably due to the gamma prime phase of the iron–nitrogen system which corresponds to the compound Fe_4N.

It is the author's opinion that it was the precipitation of the compound Fe_4N which caused most of the age hardening phenomenon observed by Hensel and Larsen[38] in arc weld metal.

Blow-Holes in Weld Metal

It is well known that the surface of the blow-holes in a freshly fractured weld are shiny and free from oxidation. For that reason it is quite evident that the gases present are not oxidizing. This shows that the blow-holes are not caused by oxygen or carbon dioxide because both of these gases are oxidizing at the temperature at which the blow-holes form in the weld.

It has been the author's experience that it is almost impossible to remove nitrogen from steel when present in small quantities, without the use of vacuum at extremely high temperatures.

The above eliminates the probability of carbon dioxide, oxygen and nitrogen as causing blow-holes and leaves hydrogen, carbon monoxide and possibly hydrocarbons as probable gases for causing blow-holes. The author has not experienced a weld entirely free from porosity when a hydrogen shield was employed. Welds made in an atmosphere which was composed largely of carbon monoxide were extremely porous—the same was true when methane was used as a shielding agent. This would indicate that the blow-holes in arc weld metal are caused, for the most part, by carbon monoxide and hydrogen, and any hydrocarbon gas which might be present.

The Effect of the Nitrogen Content of the Welding Atmosphere upon the Nitrogen Content of the Deposited Weld Metal

From mathematical considerations developed by Steinmetz,[17] it is quite evident that a change in the per cent nitrogen in the arc atmosphere would cause a considerable change in the per cent nitrogen fixed and "picked up" during the welding operation. It was therefore necessary to determine the effect of a variation in the nitrogen content of the welding atmosphere upon the per cent nitrogen in the deposited metal.

Welds were made in varying atmospheres using $^5/_{32}$ inch, 0.13 to 0.18 bare electrodes. The results thus obtained were:

Sample No.	Atmosphere	% N in Deposited Metal
G1	Pure H_2	0.0255
G2	75% H_2–25% N_2	0.0500
G3	25% H_2–75% N_2	0.0717
A27	Air	0.107
G4	Pure N_2	0.143

The shields in which these welds were made were merely pipe type shields held parallel to the side of the electrode. For this reason, some nitrogen and oxygen were present in the atmosphere when pure hydrogen was used and some oxygen was present when pure nitrogen was used. The reason for adopting this type of shield was that the box type is not commercially applicable, and these results are therefore comparable to those which are obtained when the commercial type of shield is employed.

Figure 1 shows a graphical illustration of the results and illustrates that the higher the per cent of nitrogen in the welding atmosphere, the higher will be the per cent of nitrogen in the deposited metal.

The Effect of the Carbon Content of the Electrode upon the Nitrogen Content of the Deposited Weld Metal

A series of welds were made keeping all of the welding conditions constant as possible and varying only the carbon content of the welding electrode.

In this series, all of the electrodes employed were bare, $^5/_{32}$-inch, hard drawn wire and all of the welds were made with 150 amperes and 20 volts. The carbon contents of the electrodes were 0.015, 0.15, 0.37, 0.70 and 1.0 per cent. The results of these tests are shown in Fig. 2 and illustrate that as the carbon content of the welding electrode increases, the nitrogen content of the deposited metal decreases.

It is the author's opinion that this phenomenon is partially due to the shielding action of the carbon. As will be seen in a subsequent part of this investigation, a large percentage of the carbon is burned out during the welding operation. It is very probable that the carbon monoxide and carbon dioxide formed act as a shield and decrease the opportunity for nitrogen absorption. It follows that an increase in the carbon content of the electrode would cause a greater shielding effect.

The Effect of the Electrode Size upon the Nitrogen Content of the Deposited Weld Metal

A series of welds were made, using electrodes of the same analysis and 150 amperes and 17 volts, but varying the size of the electrode. The only intentional variable in this series of welds was the size of the electrodes. It is realized, of course, that the current density varied with the different sizes of electrodes.

The analysis of the electrodes, regardless of diameter, was 0.13 to 0.18 per cent carbon, 0.40 to 0.60 per cent manganese. The results of the tests are shown graphically in Fig. 3.

The author was aware of the fact that 150 amperes and 17 volts were not the correct amperage and voltage, as regards practical application, for some of the electrodes used in this series. This does serve, however, to illustrate very clearly that an increase in the electrode diameter causes a decrease in the nitrogen content of the deposited weld metal. As will be seen in a subsequent part of the investigation, a decreased amperage in the case of the $^5/_{32}$-inch electrode would have caused an increase in the nitrogen content of the deposited weld metal, and an increased amperage for the $^1/_4$-inch electrode would have caused a decrease in the

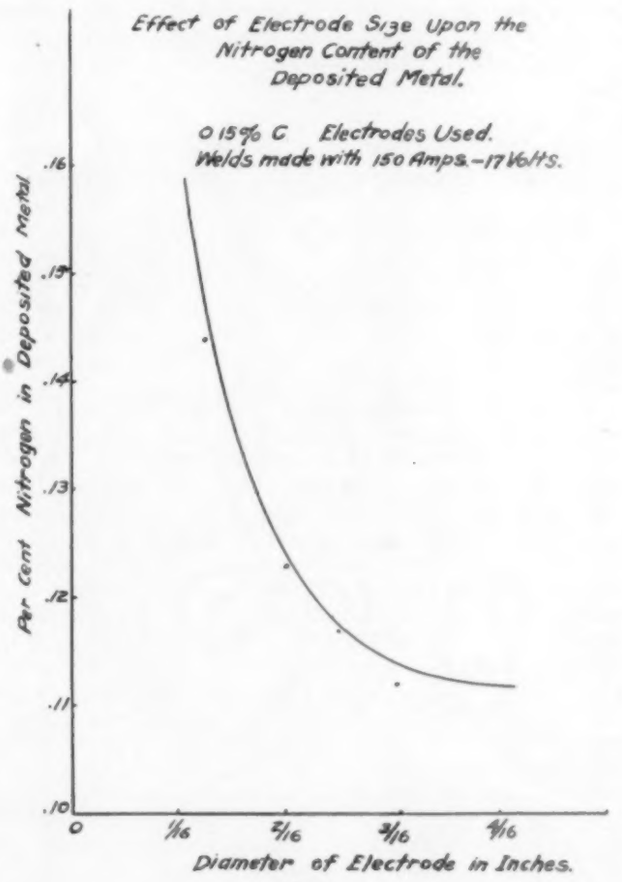


Fig. 3

nitrogen content of the deposited metal. This would indicate that, had the welds of this series been made under commercial conditions, as regards amperage and voltage, the slope of the curve in Fig. 3 would have been much more steep.

As will be shown later, the phenomenon of the absorption of nitrogen occurs on the tip of the welding electrode when straight polarity is used. It follows that the larger the diameter of the electrode, the less surface, per unit weight of metals, will be exposed to the atmosphere of the arc for nitrogen absorption. As the nitrogen absorption is a phenomenon of reaction with the surface metal, one would expect that an increase in the diameter of the electrode used would cause a decrease in the nitrogen content of the deposited weld metal. As seen in Fig. 3, this hypothesis has been experimentally verified.

The Effect of Amperage and Voltage upon the Nitrogen Content of the Deposited Weld Metal

In order to determine the effect of the amperage and voltage upon the nitrogen content of the deposited weld metal, a series of welds were made using a constant low voltage with high, medium and low amperage, medium voltage with high, medium and low amperage, and high voltage with high, medium and low amperage. The general results of the tests indicate that an increase in the amperage caused a decrease in the nitrogen content of the deposited metal and that an increase in the voltage caused an increase in the nitrogen content of the deposited weld metal. The differences in the nitrogen contents were, however, quite small as regards their magnitude.

It should perhaps be stated at this time that the author was unable to detect the difference in the nitrogen content of the deposited metal when hard drawn and annealed electrodes were used, providing other conditions remained constant.

The Influence of Reversed and Straight Polarity upon the Nitrogen Content of the Deposited Weld Metal

The question has frequently been asked as to where the nitrogen is absorbed in the weld metal and where the carbon is eliminated during the welding operation. When heavy coated electrodes are used, it is nearly always required that reversed polarity be used and the effect is that the nitrogen content of the deposited weld metal is generally diminished.

During this investigation, a large number of samples of electrode tips were obtained for chemical analysis. These samples were made by striking the arc, letting the electrode cool and carefully removing the extreme tip of the electrode. This extreme tip of the electrode corresponding to the metal which was adhering to the electrode tip in the molten state during welding and those samples will be referred to as "electrode tips." Another set of samples was made by alloying the tip of the electrode to become molten in sufficient quantities so that a drop was about to fall upon the plate metal. At this time, the electrode was given a quick "flip" and the adhering drop, which might closely correspond to arc metal, was thrown onto the plate, outside of the crater region, so that no actual fusion occurred. These drops were collected for analysis and will be referred to as "buttons." The third sample taken for analysis was from metal deposited in the usual manner. The above was then repeated, using reversed polarity.

In both the reversed and straight polarity, $^{5}/_{32}$-inch, bare, 0.37 per cent carbon, 1.0 per cent manganese electrodes were used and the welds made with 125 amperes and 20 volts.

The results of the rod tips, buttons and weld metal made with straight polarity were as follows:

Material	% C	% N
Original electrode	0.37	0.007
Rod tips	0.105	0.092
Buttons	0.115	0.110
Weld metal	0.125	0.090

As may be seen in the table of results when straight polarity is used, the nitrogen is absorbed at the tip of the electrode and the carbon is eliminated at the same place.

It should be stated that the size and shape of the samples made the carbon analysis exceedingly difficult in the case of the buttons, and it is highly probable that a small error may be present in the carbon analysis of the buttons. It was very easy, however, to obtain exceedingly accurate results in the rod tip and weld metal. There was very definite proof that the carbon was burned out at the tip of the electrode. In the case of the weld metal which had been deposited on 0.20 per cent carbon plate, there was undoubtedly some diffusion of carbon from the plate metal into the weld metal which would account for the increase of carbon from the rod tip to the weld metal.

It will be noticed in the case of the straight polarity that there is a decrease in the nitrogen content of the weld metal upon passing through the arc and into the crater. With straight polarity, the plate metal is hotter than the rod tip and again there is an indication that there is a decrease in the solubility of nitrogen with an increase in the temperature.

The results of the rod tips, buttons and weld metal made with reversed polarity were:

Material	% C	% N
Original electrode	0.37	0.007
Rod tips	0.105	0.053
Buttons	0.115	0.067
Weld metal	0.06	0.098

From the results obtained when reversed polarity was used, one sees that there was a marked increase in the nitrogen content of the metal passing from the rod tip to the crater. Also, that there was a marked decrease in the carbon content of the metal passing from the rod tip to the crater. This again shows that the nitrogen is absorbed under conditions which cause carbon to be eliminated. This may be due to the nitrogen and oxygen forming nitric oxide (NO) in the arc which reacts with the iron to form iron nitride and liberates atomic oxygen which reacts with the carbon. This seems to the author as being a logical explanation for the fact that the nitrogen is absorbed under conditions which burn out the carbon. If some atomic oxygen reacted with the iron, it would also explain the fact that weld metal containing a high nitrogen content usually contains a high oxygen content.

It is known that when heavy coated electrodes are employed which retain most of the carbon in the metal, there is very little nitrogen absorbed and the metal is quite low in oxygen. This is additional proof that conditions which lead to the absorption of nitrogen are, at the same time, conditions for the liberation of carbon and contamination by oxygen which is further verification for the theory that the nitrogen fixation, when welding in air, is caused by the nitrogen having reacted with the oxygen. It is known, however, that the electric arc is capable of breaking molecular nitrogen down into active atomic nitrogen which will react directly with the iron to form iron nitrides.

Physical Tests upon Metallic Arc Weld Metal

At the outset of the investigation, there was some difference of opinion as to the proper method of making, or depositing, weld metal for physical test specimens. It was finally decided to deposit the metal in a 90° V type of weld, which is quite common in the industry. When preparing the samples for machining, the author macro-etched each sample and center-punched it so that there would be no possibility of any plate metal being in the machined specimen.

An expert experimental welder was obtained to make

the physical test samples. This welder was quite familiar with practically every type of electrode available and made all of the welds for the physical test samples.

A seal bead was made on each weld to assist in refining the structure of the weld metal and to fill any flow holes or cavities which might have been present at the bottom of the V.

Hensel and Larsen[38] found that the aging phenomenon was at a maximum in about ten days. In this investigation, the minimum time between making and testing the weld was twenty-one days. This precaution was taken in order that the aging phenomenon might reach a maximum before any of the samples were tested. By allowing this amount of time for aging, the author was quite confident that any difference in the physical test results could not be attributed to a difference in the aging.

Duplicate welds were made varying the amperage, voltage, electrode size, carbon content, using bare, dust coated and heavy coated electrodes.

The author endeavored to plot the information of the test results but was unable to do so because of the fact that there was an insufficient number of samples used. That is to say, that the variation obtained for any given size and composition of electrode was not sufficient to warrant graphical representation. Another attempt was made to plot the physical properties against the nitrogen content for electrodes of a given carbon content, disregarding the amperage, voltage and coating used. In this case there was obtained merely a group of points at the low nitrogen contents when coated electrodes were used and another group of points at the high nitrogen contents which resulted when bare electrodes were used. The result of this attempt was merely a straight line drawn from one group of points at high nitrogen contents to another group of points at low nitrogen contents. The results were indicative but of such a nature that the author did not feel justified in including them in graphical form.

It was found that in the case of welds made with heavy coated electrodes, where the nitrogen content of the deposited weld metal was below 0.05 per cent, the physical properties of the welds were greatly improved. Between 0.02 and 0.043 per cent nitrogen, obtained when heavy coated electrodes were used, there could be no straightforward correlation drawn between the nitrogen content of the weld and the physical properties. This would indicate that between these very low limits of nitrogen contents (0.02 to 0.043 per cent) other factors, such as the cooling rate, elimination of impurities, grain size, carbon content, manganese content, etc., may have been more influential than the variation of the nitrogen content. An analogous situation was encountered in the case of the high nitrogen contents resulting from the use of bare electrodes.

This series of welds, made for physical tests, showed that in the case of weld metal deposited by the electric arc, conditions which cause a marked increase in the nitrogen content of the deposited metal, cause a decrease in all of the physical properties. Previous investigators, working with steel which contained low percentages of nitrogen, found that an increase in the nitrogen content of the steel caused an increase in the tensile strength. It will be noted that in this investigation of arc weld metal, welds made under conditions which caused a decrease in the nitrogen content had an increased tensile strength. This indicates that there are other very important factors beside the nitrogen content to be considered in the case of arc weld metal, such factors being, in the author's opinion, heat treatment, grain size, silicon and manganese contents, carbon content, oxygen content, density, etc. It should be remembered that conditions which lead to a low nitrogen content also lead to a low oxygen content and inhibit the burning out of the carbon.

It is the opinion of the author that the properties of weld metal deposited by the metallic arc cannot be accounted for by any one element, or constituent, or by any simple theory, but that the properties are probably due to combinations of elements and constituents, and they could only be explained by more complex theories.

It is evident, however, that nitrogen does play an important part in causing detrimental effects in metallic arc weld metal.

Conclusions

1. The absorption of nitrogen may be diminished by:
   - A. Increasing the carbon content of the electrode.
   - B. Increasing the amperage.
   - C. Decreasing the arc length (voltage).
   - D. Increasing the diameter of the electrode.
   - E. Maintaining a reducing atmosphere.
   - F. Using heavy coated electrodes.
2. Nitrides may precipitate at the grain boundaries or within the grain itself. Nitrogen may also cause widened grain boundaries.
3. The needles present in arc weld metal are probably the gamma prime phase of the iron–nitrogen system and correspond to the compound Fe_4N.
4. The colorless, structureless areas found in arc weld metal are probably ferrite areas which are rich in iron nitride that has not had sufficient time to segregate in the form of needles.
5. The main oxide present in arc weld metal is magnetite.
6. It is the opinion of the author that carbon monoxide and hydrogen are largely responsible for the blowholes occurring in weld metal with perhaps the assistance of hydrocarbons.
7. No difference in the nitrogen content of the deposited metal is encountered between the use of annealed and hard drawn electrodes.
8. Conditions which lead to the absorption of nitrogen are conditions which lead to the burning out of carbon and contamination by oxygen.
9. When straight polarity is used, the nitrogen is absorbed at the tip of the welding electrode and when reversed polarity is used, some nitrogen is absorbed at the tip of the welding electrode, some is absorbed when passing through the arc and more is absorbed in the crater. The carbon is eliminated under the conditions and at the time nitrogen is absorbed.
10. The nitrogen is, in an air atmosphere, probably fixed as nitric oxide (NO) in the cooler part of the arc and this is probably split up into active atomic nitrogen and oxygen, both of which may react with the metal.
11. The solubility of nitrogen in the weld metal appears to decrease with an increase of temperature at the elevated temperatures of welding.
12. Conditions under which nitrogen is absorbed in the weld metal are conditions which lead to a decrease in the values of the physical properties of the weld metal.
13. Nitrogen alone will not account for all of the inferior properties found in some metallic arc weld metal. It is the author's opinion that other factors such as heat treatment, grain size, microstructure, carbon content, manganese content, cooling rate, etc., play an exceedingly important part in controlling the physical properties.

COMPLETE BIBLIOGRAPHY

[1] A. H. Allen, "Further Experiments on the Existence of Nitrogen in Iron and Steel," *Journal of the Iron and Steel Institute*, No. 1, p. 181 (1880).
[2] H. N. Warren, "Recent Researches on the Action of Nitrogen on the Metals Iron, Copper, Nickel, Cobalt and etc.," *Chemical News*, **55**, 155 (1887).
[3] H. Tholander, *Jernkontorets Annaler*, **43**, 429, No. 7 (1888).
[4] G. J. Fowler, "On Nitride of Iron," *Chemical News*, **68**, 152 (1894).
[5] Harbord and Twynam, "A Note on the Presence of Fixed Nitrogen in Steel," *Journal of the Iron and Steel Institute*, No. 2, p. 161 (1896).
[6] Braune, "An Investigation of Nitrogen in Steel," *Stahl und Eisen*, Nov. 1906, p. 1496.
[7] Pourcel, *Revue Universelle des Mines*, Vol. 15, p. 229.
[8] Grabe, "Remarques au Sujet de L'Influence Attribuee a L'Azote sur les Proprietes des Aciers," *Review de Metallurgie*, Vol. 5, p. 353.
[9] Petren and Grabe, "The Determination of Nitrogen in Iron and Steel," *Jernkontorets Annaler*, **60**, 1 (1907).
Walter Geisen, "Special Steels in Theory and Practice," *Carnegie Scholarship Memoirs*, **1**, 1 (1909).
[10] Stromeyer, "The Aging of Mild Steel and the Influence of Nitrogen," *Journal of the Iron and Steel Institute*, No. 1, p. 404 (1909).
[11] E. D. A., "Influence of Nitrogen on Steel," *Metallurgical and Chemical Engineering*, **11**, 121 (1913).
[12] J. H. Andrews, "Iron and Nitrogen," *Journal of the Iron and Steel Institute*, No. 2, 210 (1912).
J. H. Andrews, "The Influence of Gases upon the Critical Ranges of the Iron-Carbon Alloys," *Carnegie Scholarship Memoirs*, **3**, 236 (1911).
[13] B. Strauss, "The Effect of Nitrogen in Steel," *Iron Age*, **97**, 432 (1916).
[14] Chiyeskii and Blinov, "Influence of V and Ti on the Nitrogen Content of Iron and Steel and Its Alloys," *Society of Chemical Industry*, **35**, 893 (1916).
[15] W. E. Ruder, "The Metallurgy of the Arc Weld," *G. E. Review*, **21**, No. 12, (1918).
[16] J. H. Paterson, "Electric Welding," *Engineering*, **107**, Feb. 1919, 285.
[17] C. P. Steinmetz, "Theoretical Study of Nitrogen Fixation by the Electric Arc," *Chemical and Metallurgical Engineering*, **22**, 229, 353, 411, 455 (1920).
[18] S. W. Miller, "Some Structures in Steel Fusion Welds," *Trans. A. I. M. E.*, **58**, 700 (1918).
[19] Comstock and Ruder, *Chemical and Metallurgical Engineering*, **22**, No. 9, 399 (1920).
[20] S. W. Miller, "Path of Rupture in Steel Fusion Welds," *Trans. A. I. M. E.*, **62**, 524 (1920).
[21] G. F. Comstock, "Microstructures in Iron Deposited by Electric Arc Welding," *Trans. A. I. M. E.*, **62**, 555 (1920).
[22] A. A. Blue, "An Occurrence of Nitrogen in Steel," *Iron Age*, **108**, 1 (1921).
[23] Rawdon, Groesbeck and Jordan, "Physical Properties of Arc Fused Metal," *Chemical and Metallurgical Engineering*, **23**, No. 14, Oct. 1920, 677.
[24] Rawdons, Groesback and Jordan, "Metallography of Arc Fused Steel," *Chemical and Metallurgical Engineering*, **23**, No. 16, Oct. 1920, 777.
[25] Ruder and Brophy, "Nitrogen in Carburized Steels," Chemical and Metallurgical Engineering, **25**, No. 19, 867 (1921).
[26] Jordan and Swindell, *Chemical and Metallurgical Engineering*, **27**, No. 24, 1170 (1922).
[27] J. B. Clough, "Aging of Steel with Special Reference to Nitrogen," Harvard University, D.Sc., Thesis, Dept. of Metallurgy, 1933.
[28] W. Spraragen, "Fluxes and Slags in Welding," *Trans. of the Faraday Society*, **20**, 159 (1924–25.)
[29] H. B. Ogden, "Fluxing Problems in Welding of Mild Steel with the Metallic Arc," *Trans. of the Faraday Society*, **20**, 159 (1924–25).
[30] W. E. Ruder, "Science of Electric Welding," *Journal of the Franklin Institute*, **192**, 561–83 (1921).
[31] P. P. Alexander, "Arc Welding in Hydrogen and Other Gases," *G. E. Review*, **29**, 169 (1926).
[32] Weinman and Langmuir, "Atomic Hydrogen Arc Welding," *G. E. Review*, **29**, No. 3, 160 (1926).
[33] J. Fuchs, "Influence of Nitrogen upon Electric Arc Welding," *Z. Ver. Deut. In.*, **74**, 1569 (1930).
[34] Svechnicov, "Effect of Nitrogen in Iron and Steel," *Heat Treating and Forging*, April 1929, p. 436.
[35] Homerberg and Walsted, "A Study of the Nitriding Process," *A. S. S. T., Nitriding Symposium*, **1929**, p. 67.
[36] F. Rapatz, "Harmful and Useful Effects of Gases in Steel," *Z. Metallkunde*, **21**, 89 (1929).
[37] L. W. Schuster, "The Effect of Contamination by Nitrogen on the Structures of Electric Welds," *Journal of the Iron and Steel Institute*, No. 2, p. 249 (1930).
[38] Hensel and Larsen, "Dissolved Nitrogen Embrittles Weld Metal," *Metal Progress*, Sept. 1931, p. 44.
[39] Hensel and Larsen, "Age Hardening Phenomenon in Typical Fusion Weld Metal," *Trans. A. S. S. T.*, May 1932, p. 639.
[40] J. W. Miller, "A Study of the Nitride Case in a Special Nitriding Steel," M. I. T., 1931.
[41] C. B. Sawyer, "Nitrogen in Steel," *Trans. A. I. M. E.*, **49**, 799 (1923).
[42] Fry, "Stickstoff in Eisen," *Stahl und Eisen*, **43**, 1271 (1923).
[43] Archibald, "An Analytical and X-ray Study of the Nitriding Process," M. I. T., 1930.
[44] Bramley and Jinkings, "Gaseous Cementation of Iron and Steel," *Iron and Steel Institute, Carnegie Scholarship Memoirs*, 15, 71 (1926).
[45] Hurum and Fay, *Chemical and Metallurgical Engineering*, **26**, 218 (1922).
[46] Hurum, "Nitrogen in Steel and Its Rôle in the Cementation Process," M. I. T. Thesis, 1920.
[47] Jordan and Swindell, Bureau of Standards, Scientific Paper 457, pp. 499–511.
[48] Tschischewski, *Journal of Iron and Steel Institute*, **92**, 47, No. 2 (1915).
[49] Hägg, "X-ray Investigation of the Nitrides of Iron," *Sonderdruck aus, Zeitschrift fur Physikalische Chemie*, 1930.
[50] Westgren, "Iron, Carbon, Nitrogen, Structural Analogies Revealed by X-rays," *Metal Progress*, July 1931, p. 50.
[51] Miller, "Nitrogen in Metallic Arc Weld Metal," *The Iron and Steel Engineer*, November 1934.

Assembling the New Steel Radio Tube by Electrical Resistance Welding*

By M. L. ECKMAN†

THE past thirty years have seen the devastations of a world war such as was never known before, with its aftermath of depression, social unrest, political and financial chaos.

Reviewing this period would engender a most gloomy picture of the future did we not recall that this same period of time brought forth a remarkable number of marvelous scientific contributions toward the betterment of we humans, in manufacturing, travel, social government and education.

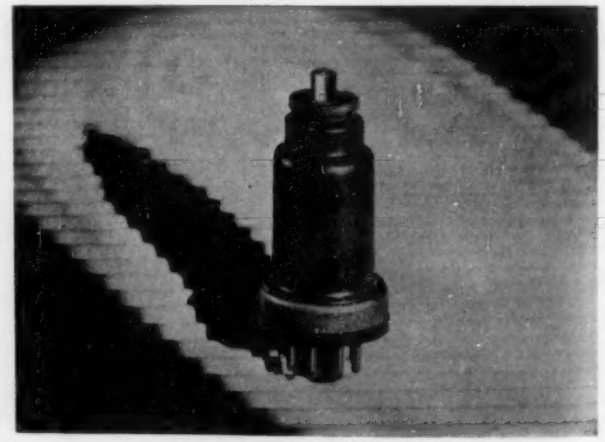
The most useful of these for the dissemination of news, knowledge and entertainment is the radio.

A close second to the radio is *Electrical Resistance Welding*, a *method of assembly* which applies electric current in its simplest form to the performance of useful work.

Considered from the point of quality, high speed production and economy, resistance welding is the world's best assembly method.

For joining sheet metal stampings as well as shafts, tubing, structural shapes and forgings.

Today's efficient, reliable low-priced radio receiver, to meet all requirements and purses, as well as our great broadcasting stations, centers around the development



The Complete All Steel Radio Tube

of the radio tube, which is really an electrical valve, whose technical functions there is no need to discuss here. Most of us thought that the radio tube had just about reached perfection since manufacturers were mounting radio receivers on standard equipment in our motor cars which we could drive over rough highways, at from 20 to 60 miles an hour, and still have our loud speakers

* Paper presented at Fall Meeting, AMERICAN WELDING SOCIETY, week of September 30, 1935, in Chicago.
† Research Engineer, Thomson-Gibb Electric Welding Company.

Fig. 2—Eyelets and Header

Fig. 3—Assembled

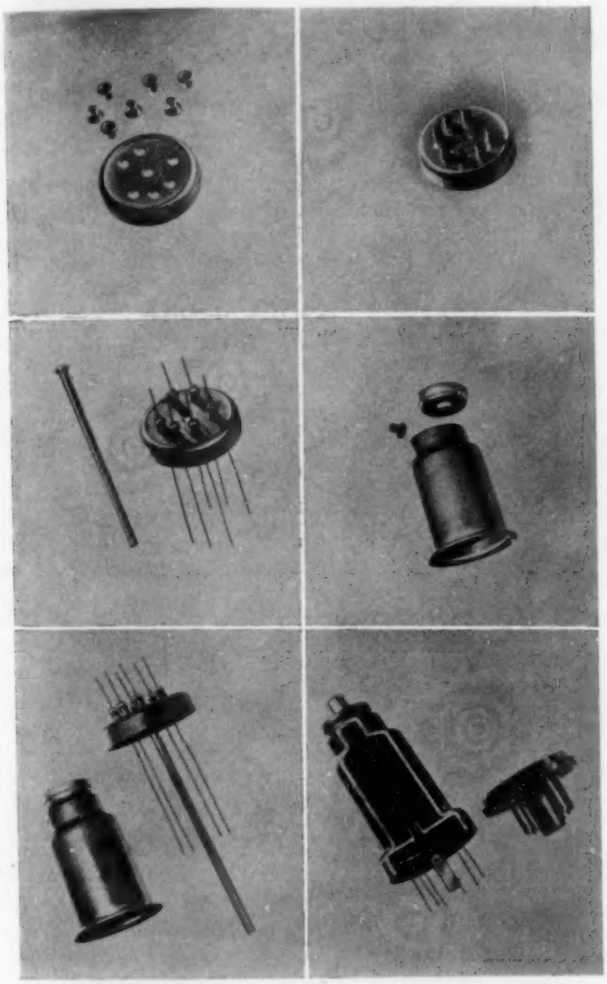


Fig. 4 (Middle)—Exhaust Tube and Header Assembly

Fig. 5 (Middle)—Shell-Eyelet and Cup

Fig. 6—Header and Shell Units

Fig. 7—Final Assembly

keep us in touch with the "stock market" and "news of importance." Even more convincing was the fact that the price of the tube had steadily fallen from $10.00 each 10 years ago to $.50 each in 1935. This indicated a standardized product practically perfect.

The earliest tube manufacturers used solder to join the various parts in their proper relation. This was rather slow and tedious as the parts had to be fluxed with a suitable agent and then soldered by holding a soldering iron against the work or dipping in molten solder.

Resistance welding reduced the time, cost and manufacturing by welding wires to filament standards, grids and plates instantaneously from 1 to 3 cycles or from $^1/_{60}$th and $^1/_{20}$th of a second, sometimes "mounts" having 60 resistance welds each.

This efficient method of assembly was an important factor in the design of the latest model of the engineering wizard of communication circuit, namely *steel radio tubes* (see Fig. 1).

	Old Style "Radio" or "Audio" Frequency Tubes	New All Steel Tubes
	Dimensions in Inches	
Outside diameter	$1^5/_8$	1
Height over-all	$3^7/_8$	3
Cubical vacuum space	5.070	1.180

There are a number of reasons for this development, chief among which are (1) compactness; (2) more efficient functioning; (3) greater accuracy in manufacturing; (4) sturdier, with longer life; (5) better assembling methods.

In the first point, the matter of compactness, the following comparison will give approximate figures.

This compactness is of more importance than appears at first glance. The old style glass tube on high grade sensitive sets had to be individually shielded by extra metal cylinder shields properly grounded. This meant distributing them over a large area in the receiver with a consequent longer connecting wiring than is required with the new steel tubes.

The new tubes being smaller in diameter with the outer shell of steel needs no extra shielding as the tube acts as a shield in itself, being integrally grounded. These steel tubes allow extraordinary close coupling of the hook-up, occupying in some cases 40% of the space of the old style tubes.

2. More efficient functioning is claimed because the steel tubes can be held to closer tolerances in size and assembly. A further claim is that any residual or generated gas in the tube after evacuation has a tendency to be absorbed by the steel shell in service.

3. Greater accuracy in manufacturing is had because the steel stampings that go to make up the assembly can be "worked" to precise limits and "higher speeds."

Assembling by resistance welding is held to an exactitude not possible with glass construction.

4. Steel tubes have all the strength and sturdiness, inherent in steel over glass. Fragility is not a characteristic of the new tube.

5. The assembling of the new steel tubes by electrical resistance welding is much speedier and more economical than on the older type tubes. Speeds of from 25 to 30 per minute is now a fact with higher speeds possible, as operators become more proficient.

A great deal of development work had to be done by engineers to make the steel tube a real production article.

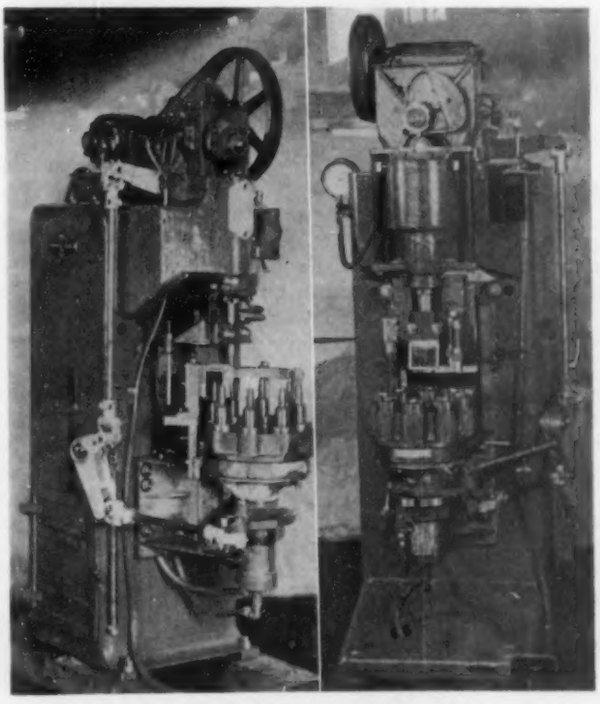


Fig. 8—Press Welders and Rotary Index Table

For instance the "header" assembly—see Figs. 2, 3 and 4—is a cup shaped stamping made of 0.040-in. steel that had to be provided with a means of sealing and insulating the terminal wires from the socket prongs to the "mount" as the filament, grid and plate assembly inside the tube is called. Glass is the accepted sealing and insulating material, but this has a much different coefficient of expansion than ordinary steel, so it was necessary to develop a material that would have the same coefficient of expansion as glass and an alloy material called "Fernico" was developed which is an alloy of iron, nickel and cobalt covering the range from 0 deg. C to 350 deg C. Eyelet stampings of 0.020-in. thick material were made with the body of the eyelet 0.120 in. in diameter and the head 0.203 in. These were dropped through the 0.125-in. holes stamped in the header and from 5 to 7 eyelets, depending on the type of tubes were simultaneously welded on a No. 2 press welder of 175 kva. capacity (Fig. 8).

This weld joins the head of the 7 eyelets a total of 4 inches 0.466 of linear welds in 4 cycles of welding time or $^1/_{15}$th of a second drawing 150 kva. and using 1900 lb. electrode pressure and a speed of 30 per minute.

The "header" has a hole punched in the center for welding the exhaust tube which had a head on it similar to the eyelet. This weld is made on a No. 1 press welder (Fig. 8) in 1 cycle of time or $^1/_{60}$th of a second using a pressure of approximately 600 lb. at a speed of 25 per minute.

The "header" has a ring projection embossed on the flat side where it is welded to the "shell" 0.045 in. wide, 0.025 in. high and $1^3/_{32}$ in. in diameter as shown in Fig. 2.

The "shell," see photograph 5, has a 0.125-in. dia. hole pierced in the top center. This shell is made of 0.030-in. full finished sheet steel stock by stamping and drawing. In this center hole an eyelet is welded for sealing in the top terminal wire on a No. 1 welder with a rotary indexing table in one cycle at a speed of 25 per minute.

The "cap" as shown in tube photograph No. 5 is also welded at the same time as the eyelet.

You will note that the shell has a flange stamped on the bottom of it $^3/_{32}$ in. wide for welding to the ring projection on the "header."

Copper alloy wires with fused glass beads are inserted in both the header and the shell eyelets and fused to the same with a regulated gas flame.

The "mount" is next assembled to the header and welded to the lead-in wires, then the "header" and "shell" are ready to be assembled by resistance welding the flange and ring projections together in a No. 2 press welder. This weld is 3.438 inches linear and it necessitates 1900 lb. electrode pressure and is made in 4 cycles or $^1/_{15}$th of a second at a speed of 32 per minute.

The long exhaust tube, see Figs. 4 and 6, is used to exhaust the air from the tube, then the tube is pinched shut and welded on a pinch welder giving the result as shown in Fig. 7. This is done in 2 cycles or $^1/_{30}$th of a second on a 25 kva. welder with 600 lb. pressure and the speed is 25 per minute. It is remarkable when considered that all of these welds must be pressure tight as the completed tube is exhausted of all air and sealed off, maintaining the vacuum over the entire length of life of the tube under all working conditions.

Working at the high speed production which is required, Elkonite grade 30W3 has been found to be most efficient and even then at this high speed production, it is necessary to change electrodes every 2 to 8 hours in order to maintain the high standard of quality, the variation in time being dependent upon the particular type of electrode being used and its service requirements. This has been arranged to be done very quickly and efficiently with interchangeable dies accurately located within 0.001 in. in the rotating index table and in the upper electrode holder.

The Raytheon Corporation of Newton, Mass., is able to maintain at the present time a production of 15,000 tubes per day with a possibility of increasing this production up to the capacity of the machine.

Composition of Electrode Coatings

By C. J. HOLSLAG†

AS the father of covered electrodes in this country I think it is my privilege to explain as to the composition of metals and coatings of the shielded arc.

First and foremost, there is in every coating a silicate, commonly silicate of soda but sometimes aluminum silicate (clay) or magnesium silicate (talc) or potassium silicate in place of sodium.

One of the first welding rods, historically, was wrapped with a ferrous silicate, being blue asbestos, stuck together with a slight amount of sodium silicate and with an aluminum wire interwound as a fluxing and quieting reagent. The other rods all contain silicate as a binder and because it helps quiet the arc, that is, prevents boiling, a slight amount of silicate in the weld makes an improved deposit. Silicon is in every welding rod. Silicate also prevents organic substances from reaching the kindling point, which has become another important function of silicate in the coating.

The next most important constituent, present in all rods, is a product of the calcium Stronum family, calcium being the most popular because of its cheapness; which family has the phenomena of lowering the temperature of which an arc will hold, or if you prefer, it increases the electronic emissivity. Lime or calcium carbonate is the most popular form for this action.

Chalk is a common material used and it also helps a great deal the action of phenomena and overhead and vertical welding.

The third and latest improvement is the addition of organic materials such as string, flour, oatmeal, sawdust, tar, gum, resin and here is where you have to dodge the patents of each particular user.

Another popular material of this characteristic is furnished by Johns-Manville Company—powdered coral.

A fourth fluxing reagent, generally aluminum magnesium (flash), titanium oxide, sub-oxide of boron or some other material are equally anxious to grab off oxide or to keep the weld from doing so. A chemical fluxing reagent is now a part of every shielded arc.

As to the metals themselves the best bare rod is the one to start with and some work has been done on fluxing or cleansing materials in the rod itself but while tensile and elongation can be increased in that manner; the only ductile properties so far have come from rod coverings. Of course alloy and non-ferrous rods each have special coatings but here again the main coverings as outlined above are used leaving out the fluxing reagent in the case of aluminum, adding special alloying metals for stainless, etc. As a matter of fact, alloying can be done entirely in the covering and manganese and stainless rods can be made with a mild steel electrode.

† Electric Arc Cutting Welding & Company.

The Phenomenon of the Erratic (Unstable) Welding Arc

By G. M. TICHODEEV†

Two types of welding arc with bare electrodes are discussed. The influence of certain elements present in the wire on the formation of an arc of the erratic type is shown. A physical explanation of the causes of the erratic arc formation and of the abnormal transfer of fluid metal is given.

1. Introduction

THE mechanism of the transfer of metal in the welding arc has been up to the present time an interesting subject for investigation. Such inexplicable phenomena as the extremely short-timed transfer of fluid metal when the arc is short circuited, or its transfer against the gravity are successfully explained by the action of pinch-effect.[1]

Pinch-effect is the following phenomenon. If a current of constant density in any point of the cross section flows through a cylindrical conductor, the highest induction of the magnetic field created by this current will be at the circumference of the conductor, decreasing toward its center to zero. Hence, owing to the tension of the magnetic lines, the conductor carrying the current will experience a force directed to the center, and if the cylindrical conductor is a liquid, then a hydrostatic pressure will be created within it having a maximum in the center and decreasing to zero on the circumference. The value of the hydrostatic pressure in the center may be calculated from the formula, derived from the law of mutual action of the current and the magnetic flux, and it is proportional to the square of current density.

According to F. Creedy, the transfer of metal in the welding arc takes place in the following way. At the base of the fluid drop of metal in contact with the solid part of the electrode, there is always a reduction occurring from the moment of the formation of the drop, and the highest hydrostatic pressure will be in the center of the reduced section. Owing to the fact that the fluid metal is to a certain degree viscous, the neck in the reduced place will become more and more narrow due to influence of the pinch-effect, while the hydrostatic pressure will become higher and higher. The result is that the created force, the value of which remains constant, will separate the fluid drop from the end of the electrode.

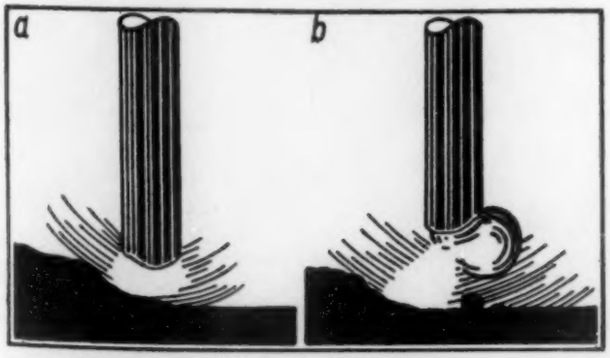


Fig. 1

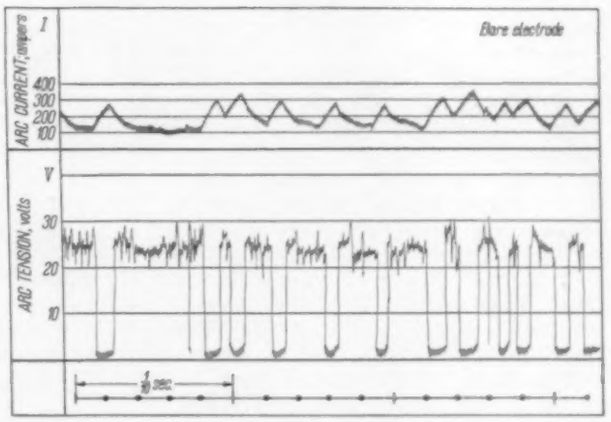
The phenomenon of the erratic arc confirms the certainty of this view of the mechanism of metal transfer.

The purpose of this investigation was to find the causes of the formation of the erratic type welding arc.

2. Experimental Part

We have applied the term "erratic arc" to the welding arc having the following external characteristics. The tension of the arc increases approximately to 25 v instead of the usual 16–18 v. The burning of the arc is unstable and makes a large noise; at the end of the electrode the fluid drop becomes large and vigorous spattering takes place as well as the falling of the drop. The cathode spot is wandering on the lateral surface near the base of the formed large drop of fluid metal. When such an electrode is connected to the positive pole the phenomenon of instability disappears and the welding

Fig. 2



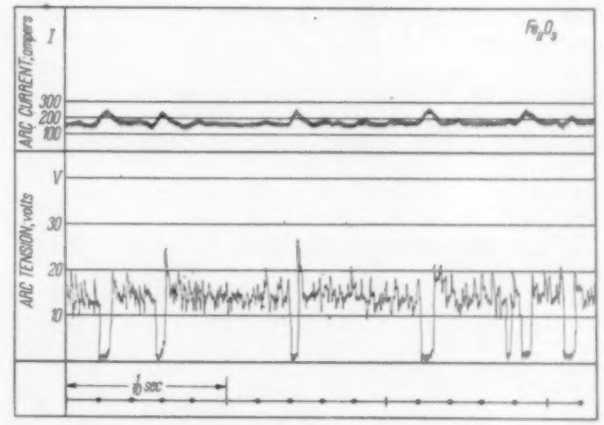


Fig. 3

† Central Institute of Metals, Leningrad.

[1] F. Creedy, R. Lerch, P. Seal and E. Sordon, *Trans. Am. Inst. E. E.*, June 1932.

properties of the electrode become the same as those when welding with normal electrodes at the reverse polarity is being carried out. Such an electrode lacks, as it is said, the "Kletterfähigkeit"[2] and it is therefore impossible to deposit the metal on the plates arranged vertically or overhead.

The existence of two fundamental types of welding arc and correspondingly of two kinds of metal transfer was found earlier by A. Hilpert[3] in his experiments with slow motion pictures of the arc. A. Hilpert also distinguishes a stable and an unstable arc and the fact that in the first case the transfer of metal takes place when the arc space is short circuited and in the second case that the transfer of metal may take place when there happens the fall of the drop from the end of the electrode without short circuit.

As we used for our experiments a set of carbon steel wire of different chemical composition, we observed that all the types of this wire caused the formation of the erratic arc. The wire was made of steel melted in a small laboratory high frequency furnace in an acid crucible by the silicon-reduction process. The difference between these kinds of wire and the usual electrode wire is that they contained silicon in excess, namely, from 0.21 to 0.24 per cent. Microscopical investigation showed the presence of a large quantity of non-metallic oxide inclusions, spread longitudinally in the direction of drawing.

Some specimens of the wire were subjected to quantitative analysis for the determination of non-metallic inclusions. Samples were taken from rods 8 mm. in diameter. As the method of quantitative analysis for the determination of non-metallic inclusions does not give very exact data, especially in such cases when the samples are taken not from ingots but from wire or rods that are subjected to severe deformation in hot or cold condition, the results of the analysis obtained could be taken only as approximate. The total amount of inclusions amounted in some specimens to 0.060 per cent of the weight of the sample; the content of SiO_2 amounted to 0.045 per cent. In some specimens of wire a high content of Al_2O_3 amounting to 0.007 per cent was found. These results brought the idea to examine the influence of SiO_2 and Al_2O_3 on the stability of the welding arc.

When welding with this rod is carried out with the automatic arc welder, all the poor properties of this rod display themselves very distinctly. If the automatic welder is regulated for a short arc with the normal electrode wire, then in case a wire having bad welding properties is substituted, it is impossible to obtain a good weld.

All the above-mentioned phenomena of the unstable arc are manifested so distinctly that it is easily possible to distinguish between wires with good and bad welding properties. We have taken this circumstance in view in this work when investigating the factors influencing the stability of the welding arc.

Figure 1*a* shows schematically a welding arc of the stable type. The cathode spot is situated here on the front surface of the end of the electrode.

Figure 1*b* shows schematically the erratic arc. The cathode spot is situated near the base of the large drop of fluid metal.

Two sorts of electrode wire, *A* and *B*, were taken for the experiments: *A* wire was free of non-metallic inclusions and had good welding properties; *B* wire contained impurities and had bad welding properties. The chemical analysis of these two wires is given in Table 1.

Thoroughly cleaned surfaces of specimens of these wires were finely threaded. To investigate the effect of non-metallic inclusions on the burning of the arc, the inclusions were taken in the form of minerals crushed to fine powder. When the powder was put on the surface of the rod it sank and strongly adhered to the base of the threading. The rods were fused on the automatic welder regulated for operation with a short arc using normal electrode wire. As mentioned above, the use of the automatic welder gives the possibility to distinguish between the wires with good and bad welding properties.

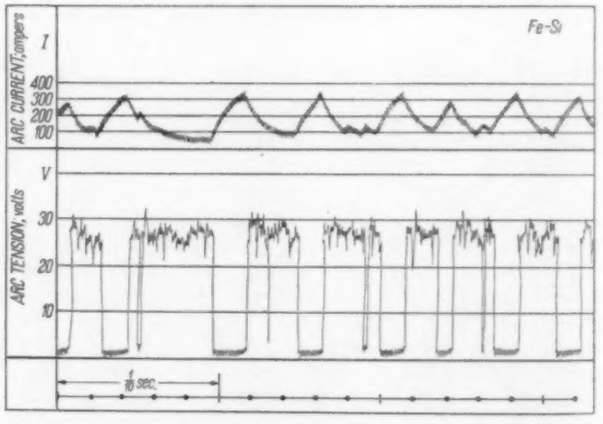
Table 1—Chemical Composition of the Wire

		Chemical Composition				
	Diameter	C	Si	Mn	S	P
Wire	in Mm.	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
A	5	0.07	Traces	0.37	0.044	0.021
B	4	0.07	0.22	0.42	0.014	0.016

The experiments were divided into two groups. The first group included the investigation of coatings put on the surface in very small amounts from some thousandths to the tenths of 1 per cent of the rod weight. The second group comprised the investigation of the effect of different treatment of the wire, namely, of annealing, pickling, liming and drying after pickling, etc. While the experiments of the first group were designed to throw light on the question of the influence of non-metallic inclusions on the stability of the arc, the purpose of the second group experiments was to find the effect of the technological processes of wire production.

The oscillograms of arc tension and current on Figs. 2–5 show the typical differences caused by covering the surface of the rod with different powders. A part of

Fig. 4



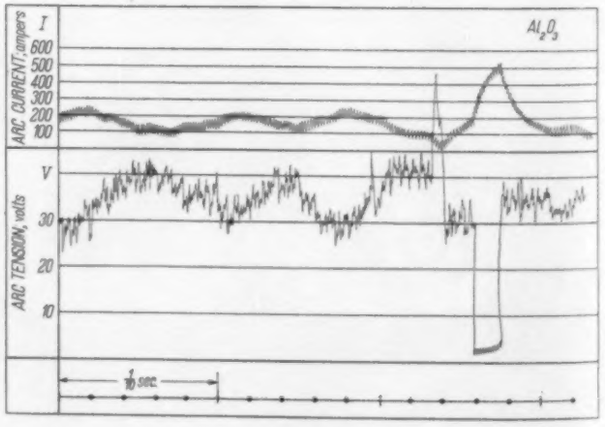


Fig. 5

[2] The term "Kletterfähigkeit" is taken from German technical literature.
[3] V. D. I., 1929, No. 23, Amer. Welding Soc. Journal, No. 7 (1933).

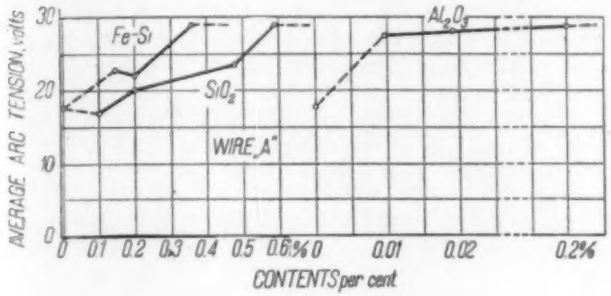


Fig. 6

arc oscillogram for *A* rod with bare surface is shown on Fig. 2. The average arc tension is equal approximately to 23 *v* varying within ±2.5 *v*; the number of short circuits per second that may be seen on the oscillogram is equal on the average to 28. After coating this rod with a small amount of ferric oxide (Fe_2O_3), the curves of arc tension and current become of a far more stable character; this may be seen on the oscillogram of Fig. 3. The average tension of the arc decreases to 15 *v* but the number of the observed short circuits does not change considerably. A thorough examination of the oscillograms brings to the supposition that in some cases the short circuits were not registered by the oscillograph, due to the rapidity of the process.

When the rod is coated with ferrosilicon (containing 75 per cent of Si), the stability of the arc falls considerably (Fig. 4). The average tension increases up to 28 *v* and higher; the tension variations are also high. Alumina exerts the most considerable influence on the decrease of arc stability (Fig. 5). The average tension amounts here to 37.5 *v*; the tension variations are equal to ±10 *v*; the number of short circuits per second decreases to 1–2.

The increase of tension of the arc of the erratic type is accounted for by two reasons. Firstly, when there is the same average distance between the end of the rod and the steel plate, the length of the positive column increases due to the formation of the cathode spot near the base of the drop. Secondly, the gaseous space of the arc has a lower temperature, since due to the wandering of the cathode spot a transfer is also taking place in the positive column.

The influence of any surface coating is therefore further characterized by the value of the average arc tension as registered by the voltmeter when the welder is adjusted for a normal short arc and the current in the arc is constant, being 195 A for *A* wire and 150 A for *B* wire.

Figure 6 shows a graph of the average arc tension variation when melting *A* rod covered with different amounts of ferrosilicon, silica and alumina. It may be seen from the graph that when the rod is covered with 0.15–0.20 per cent of ferrosilicon that corresponds to 0.12–0.15 per cent of Si, no special disturbance of the normal burning of the arc happens. But when the content of Si amounts to 0.36 or 0.27 per cent, the arc becomes of the erratic type and the average tension increases to 28 *v*. When the content of SiO_2 is equal to 0.04–0.20 per cent, it exerts no influence, while the amount of 0.48 per cent of SiO_2 that corresponds to 0.22 per cent of Si causes the appearance of all the typical signs of the erratic arc. Such an effect but in a still stronger degree is to be observed when the rod is coated with Al and Al_2O_3. In our experiments the surface layer of Al_2O_3 was equal to 0.0095 per cent and this amount was sufficient to make the arc erratic.

Different mixtures of stabilizing oxides together with SiO_2 and Al_2O_3 did not exert any influence on the stability of the arc, as if the opposite properties of the components present in these mixtures compensated each other. When connecting a rod coated with SiO_2 or Al_2O_3 to the positive pole, the phenomenon of the erratic arc disappeared.

The resulting curve giving the change of the average arc tension as related to the coating of the surface of the rod is shown in Fig. 7. It may be seen that all these materials in the amounts shown on the curve may be divided into three groups.

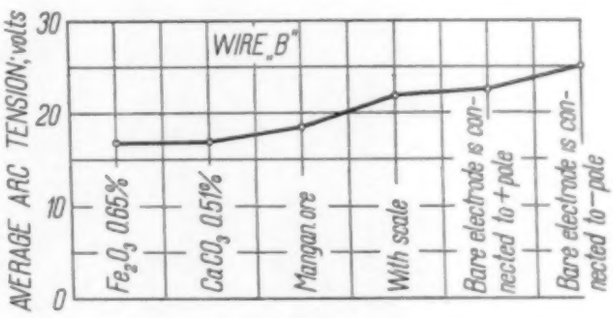


Fig. 8

To the first group—arc stabilizers—belong such materials as $CaCO_3$, $CaCl_2$, Fe_2O_3, manganese ore, etc., that act on the welding arc as stabilizers when present in comparatively small quantities—about 0.6 per cent in our experiments.

The second group includes such materials that make neither worse nor better the stability of the arc. To this group belong such mixtures as, for instance, SiO_2 + Fe_2O_3, Al_2O_3 + Fe_2O_3, etc., in definite proportions. FeS is also to be included in this group although when used in a certain proportion FeS may also increase the stability of the arc, as it was found from the oscillograms.

To substances of the third group which we have called non-stabilizers, in connection with the action they exert, belong such materials as Al, Al_2O_3, Si and SiO_2. They make worse the stability of the arc when present even in very small quantities.

A graph of the variation of the average arc tension when *B* rod that has poor welding properties was being melted is shown in Fig. 8.

The experiments that were carried out to examine the effect of different wire treatment have elucidated the following facts.

When the annealed rod covered with a thin layer of scale was being melted, the stability of the arc increased in the same degree as when the rod was covered with stabilizers. This influence was exerted by the scale. The fact that it was effected by the scale and not by any other factor such as the change of microstructure or decarburization of the surface layer was confirmed by the

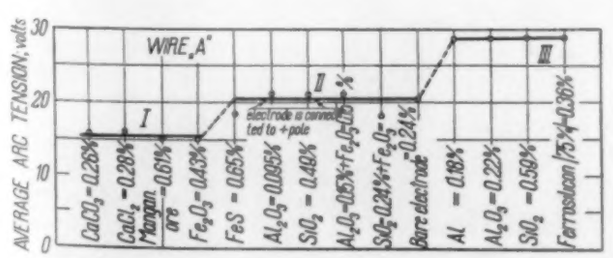


Fig. 7

experiment when the scale was cleaned off with the result that the rod acquired all its primary properties.

When the rod was pickled in a solution of sulphuric acid without subsequent liming, the arc operation was of the same unstable nature as when the rod was coated with Al_2O_3 and SiO_2. Drying without liming did not improve the stability of the arc. As the drying of the rod after etching at the temperature about 115° is carried out to eliminate the hydrogen occluded by the surface, it is to be assumed that hydrogen is not the cause of the erratic arc formation.

$FeSO_4$ is another product of reaction during pickling and it may remain on the surface of the wire that has been insufficiently washed in an alkaline solution. In order to investigate the influence of this salt on the rods that were not pickled, the latter were covered with small amounts, about 0.15–0.34 per cent, of the crystalline salt $FeSO_4$. This caused the same effect of the erratic arc. The average voltage variation for different treatment of rods *A* and *B* is shown in Fig. 9.

3. Discussion of Results

To understand the cause of the erratic arc formation, we must proceed from the relation between it and the cathode spot and the conditions of the cathode spot formation on the surface of fluid metal.

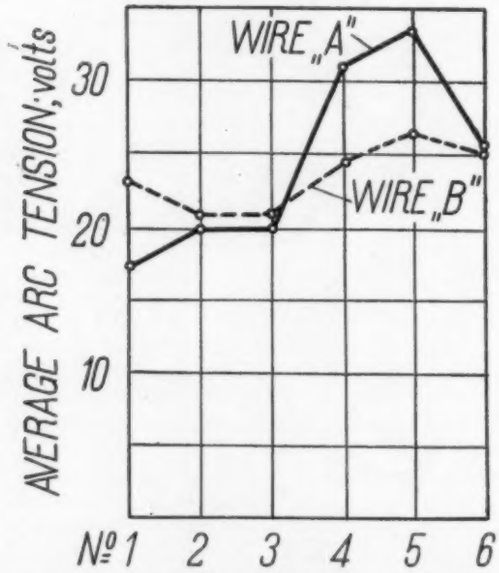


Fig. 9—No. 1. Wire as Annealed, Scale Removed. No. 2. Wire Annealed, Etched, Washed in Lime Solution and Dried in Air at Room Temperature. No. 3. Wire Annealed, Etched, Washed in Lime Solution and Dried at 115° C. No. 4. Wire Annealed, Etched and Dried at 115° C. No. 5. Wire Annealed, Etched and Dried at Room Temperature. No. 6. Wire Annealed and Covered with Fe_2SO_4 (0.34%) after Removing the Scale

The physical interpretation of the importance of the cathode spot as the place of electron emission makes clear the cause of the erratic arc formation. It is known that different substances have different ability for the thermal electron emission. Alkaline and alkaline-earth metals give the most intense emission. The significance of coating the rod with chalk lies in the fact of adding calcium oxide on the surface of the fluid drop as this oxide facilitates the electron emission. The oxides of iron and manganese probably act in the same way. Iron and manganese, which are in the periodic system of elements in the same period with calcium and have the same structure of the layer of valent electrons as calcium, form oxides that act in the same way with regard to the electron emission. We have only to assume that these oxides are distributed at the end of the electrode in such a manner that the cathode spot meets the most favorable conditions to have a steady position. Up to the present time it is unknown of what kind these conditions should be, having in view that the transfer of metal is simultaneously taking place and consequently the passing of current through the fluid drop of metal to the cathode spot should contribute to the metal transfer. The analysis of these phenomena is an independent and difficult problem.

The oxides Al_2O_3 and SiO_2 have quite different properties with regard to the electron emission. (We have in view only Al_2O_3 and SiO_2, since Al and Si when present in the rod are oxidized during fusion into Al_2O_3 and SiO_2 and the final results will be the same.)

In Table 2 are given data on the value of the emission current from the platinum wire covered with oxides of different elements. Although these data show that the temperature of red-hot wire when it was being coated with oxides of alkaline-earth elements was much lower than when it was being coated with Al_2O_3 and SiO_2, the electron emission nevertheless decreases for the second case.

Table 2—The Emission Current from the Red-Hot Platinum Wire Coated with Oxides of Different Elements

Oxide	T° Abs.	Emission Current Density A/Cm.²
MgO	1600	1.02×10^{-1}
CaO	1400	2.19×10^{-1}
BaO	1200	3.55×10^{-1}
Al_2O_3	1873	6.2×10^{-7}
Al_2O_3	2200	5.9×10^{-3}
SiO_2	2200	8.5×10^{-1}

In the case when there is not a sufficient quantity of stabilizers on the surface of fluid drop and when instead of it non-stabilizers are present there, the conditions of the cathode spot formation will be quite different. The cathode drop will wander on the surface of the drop in search of a most suitable spot where the electron emission might readily take place; such a spot is the surface, covered with the slag film of oxides of iron, manganese, calcium and other similar elements. When such a rod is coated with sufficient quantities of stabilizing substances, the deleterious effect of Al_2O_3 and SiO_2 is neutralized. The wandering of the cathode spot ceases, although the favorable arrangement of the stabilizing substances is sometimes disturbed and this results in the decrease of the arc stability.

The reason why in case of the erratic arc no normal transfer of metal can take place is quite clear. If a large mass of fluid metal has formed at the end of the electrode, as shown in Fig. 1*b*, then due to the cathode spot formation somewhat on the lateral surface near the base of the drop, the parallel direction of the imaginary current filaments passing through the reduced cross section is disturbed. This drop is blown off aside and it may pass to the base metal only under the influence of its gravity. Thus the conditions for the appearance of pinch-effect are disturbed here and consequently the normal process of metal transfer is also disturbed.

We have already shown in another work[4] that a drop of fluid metal at the end of a bare electrode carries fluid slag that consists of the products of the oxidation of iron and other elements. The surface materials get mixed

[4] Cp. "On the Question of Physico-Chemical Phenomena in the Process of the Transfer of Adding Metal during Arc Welding."

with the products of oxidation and change the quantity and composition of slag that covers the fluid drop. If the drop is covered by a thin film of fluid slag, then the conductivity of the slag also exerts an influence upon the stability of the welding arc. The measurement of the conductivity of fluid slags of different composition have shown that the conductivity of the slag decreases with the increase of the content of SiO_2 and Al_2O_3. Corresponding data are given in Table 3.

Comparing with the conductivity of fluid iron equal to 0.4 $m/\Omega \times mm.^2$, the conductivity of slag is 10^4 times

Table 3—The Conductivity of Fluid Slags

Slag No.	Slag Composition, Per Cent FeO	CaO	MnO	Al_2O_3	SiO_2	MgO	P_2O_5	Conductivity $\times 10^4$ m/Ω × mm.² 1350°	1500°	2000°	Author
1	70.5	...	...	..	29.5	..	..	4.49	5.57	13.56	
2	29.3	38.0	...	..	32.7	..	..	0.59	1.10	3.72	
3	27.0	24.6	4.0	5.4	39.0	..	..	0.41	0.99	3.62	Weinarth
4	44.5	4.35	5.5	7.95	37.7	..	..	0.91	1.82	6.43	
5	33.6	5.2	6.7	9.6	44.9	..	..	0.29	0.54	1.90	
6	33.23	25.59	10.33	5.42	13.42	3.02	1.50	0.91	1.0	1.11	
7	14.70	33.11	17.65	5.35	18.06	6.87	0.94	0.78	0.83	0.95	Haneev

smaller. These data show also that the conductivity increases with the increase of FeO content in the slag (cp. the slags Nos. 1 and 5; 3 and 4; 6 and 7), CaO probably decreases the conductivity of the slag (cp. slags Nos. 1 and 2). SiO_2 considerably decreases the conductivity of the slag (cp. slags Nos. 4 and 5).

The slag conductivity exerts an influence on the welding arc independent of the fact to what pole the electrode is connected. Nevertheless the low conductivity of the slag exerts the greatest influence when the rod is connected to the negative pole, since the base of the arc at the positive pole occupies a greater area as compared with the area of the cathode spot, and besides the temperature at the anode may be higher.

4. Summary

1. There exist two principal types of iron welding arc with bare metallic electrode. The first type is a stable arc and the second type an instable or erratic arc. The latter is characterized by the unstable burning due to the wandering of the cathode spot on the surface of a large fluid drop at the end of the electrode. This work has proved that the formation of both types of arc depends on the presence in the rod—in the alloy or on the surface—of certain substances either in the form of pure elements or their oxides.

2. FeO (Fe_3O_4, Fe_2O_3), CaO ($CaCO_3$), MnO, FeS, etc., belong to the stabilizers of the arc, i.e., to such substances that contribute to the stability of the arc.

Al_2O_3 (Al), SiO_2 (Si), $FeSO_4$ belong to the non-stabilizers of the arc, i.e., to such substances that decrease the stability of the arc. Al and Al_2O_3 are the most effective non-stabilizers; they cause the formation of the erratic arc when their quantity is less than 0.01 per cent. Si exerts a deleterious effect when its amount is over 0.15 per cent and SiO_2 when its amount is over 0.40 per cent.

3. The above statements lead to the conclusion that the electrode wire for automatic arc welding and hand welding without coating should contain no Al and not more than 0.1 per cent of Si. Deoxidation of steel with aluminum may also cause the presence of Al_2O_3 in the wire in the form of non-metallic inclusions in the amount sufficient to impart poor welding properties to the wire. And on the other hand when the rod contains non-metallic inclusions rich with FeO, MnO and CaO, the welding properties of the rod become better.

4. The experiments have shown that undue pickling of the wire in a solution of sulphuric acid to remove the scale may also cause the erratic arc formation. This may result due to insufficient washing of the wire (after pickling) in an alkaline solution to remove the remaining acid and the product of reaction $FeSO_4$.

5. The effect of stabilizers and non-stabilizers on the stability of the welding arc may be accounted for by their relation to the electron emission, when they are on the cathode surface in the form of slags in liquid state. The deleterious effect of films of slag rich with oxides of Al_2O_3 and SiO_2 may also consist in the fact that such slag will be less conductive than the slag rich with oxides of FeO, MnO and CaO.

6. When the arc is of the erratic type, the normal transfer of fluid metal from the end of the electrode to the base material is disturbed due to the absence of pinch-effect and the short circuit of the arc when the cathode spot is unfavorably situated on the lateral surface of the fluid drop. In this case the transfer of metal takes place due to gravity.

Arc Welding Used in Framing Large Residence

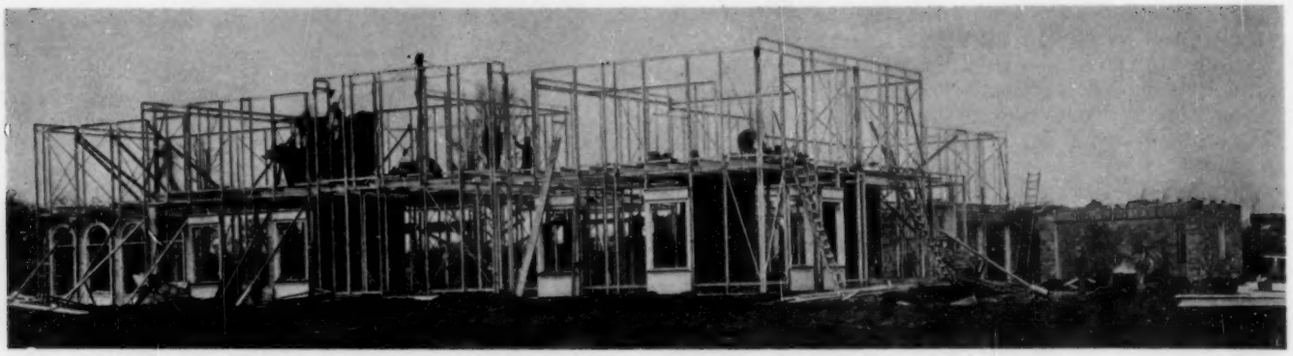
By W. T. COOK†

"HEARTHSTONE," a home of unusual size now under construction at Ottawa Hills, Ohio, employs the largest welded steel frame ever used in a residence. Walls and floor together use a total of 45 tons of steel, and the application of arc welding has been so successful that the cost of the completed steel frame was approximately 6 per cent of the total cost of the house, or only 2 per cent more than comparable wood frame and floor joists. Both shop and field welding were employed.

Architecturally, the house is of Georgian style with a richly textured stone veneer in pleasing contrast with white wood trim and entrance motif. The home is luxuriously complete in its planning and the building itself is of considerable extent. The plan is L-shaped, each arm of which is over 100 feet in length.

In designing the structure, architect Myron T. Hill, of Toledo, and structural engineer C. Merrill Barber, of Cleveland, achieved a logical steel frame which is economical, efficient, well-insulated and free from special

† News Bureau, General Electric Company.



Arc Welding Used in Framing Large Residence

patented features and interference with architectural features.

Floors are constructed of 8-inch channels or beams, spaced 3 feet to 3 feet 6 inches on centers, covered with a rib lath upon which $2^1/_2$ inches of concrete are poured. The finish flooring is laid over the concrete. Metal lath and plaster on the bottom of the floor members furnish the ceilings for the rooms below. Complete floors were poured at first-, second- and third-story levels.

The walls are composed of large shop-welded panels, one story in height, using standard 3-inch channels as studs, angles and plates, etc., as necessary. All wall panels were detailed to be less than 10 feet by 18 feet in size so that they could be hauled safely from the assembly shop to the site. The largest panels weigh only 500 pounds, so that four men were able to handle the erection with the aid of a small A-frame made of 4-inch timbers.

Bearing plates were set to level on top of the basement wall. First-story panels were placed and temporarily bolted together. First-floor beams and channels were placed; then all first-story steel was aligned and welded. Second-floor beams were placed, wall panels next and the second story welded. Third-floor beams were placed and welded. Total erection required only ten working days for four structural iron workers and a foreman.

All welding, whether in the shop or in the field, was done with the electric arc, using a portable welding generator driven by a gas engine for the field work. The electrodes used were of the heavily coated type. One-quarter-inch fillet welds were used almost entirely.

By the use of girt angles on the inside of the wall frame as support for the floor steel, no interference is encountered in placing pipes, ducts and conduits. The stone veneer is securely fastened to all exterior studs at regular spacings to provide mutual stiffening. Interior studs have horizontal tie-straps.

The use of the all-welded steel frame, together with 5-inch stone veneer, metal lath and plaster, and air spaces filled with waterproof mineral-wool insulation, thoroughly meets the desire of the owner for a fireproof home with minimum upkeep and elimination of shrinkage and settlement cracks.

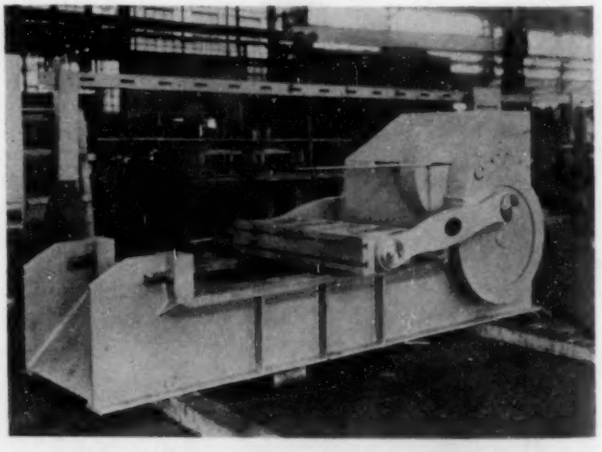
Bending Brakes and Bulldozers Bettered by Welded Construction

By MERRITT L. SMITH†

NOT to obtain lower costs or more rapid production, but as a means of assuring a better, sturdier product, the Steelweld Machinery Co., Cleveland, Ohio, has turned to all-welded construction in the bending brakes and bulldozers that it manufactures.

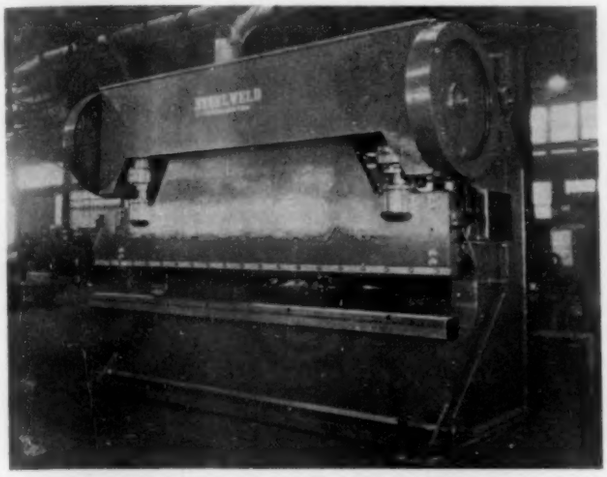
Bending brakes are subject to many kinds of abuse. With older designs, an unnoticed piece of stock in the bottom of a die, or the setting of a ram a little too close, might result at any time in sufficient overload to fracture a housing or to cause misalignment. New parts could not always be obtained quickly and such mishaps frequently meant a serious loss of time, or a badly disrupted production schedule, for the shop using the machine.

While more costly than previous methods, all-welded construction of the Steelweld Machinery Co. brakes provides machines that, the manufacturer claims, cannot be damaged by ordinary accidental overloads. Housings, which in previous models had been simple steel plates, are now carefully designed box sections with much deeper throats. Beds, rather than being just slabs of steel, have evolved into heavy I sections. Crowns,



Welded Construction Improved This Bulldozer, Both Structurally and in Appearance

† Advertising Manager, Metal and Thermit Corporation.



All-Welded Bending Brake Made by Steelweld Machinery Co.

instead of merely taking bearing thrusts, have become integral parts of the beds and give added rigidity to the entire machine. The net result is a monolithic structure that is said to have maximum strength where strength is needed most. Such a structure was impossible to build with castings or with the type of slab steel construction formerly used.

Additional features made possible by redesigning for welding are: (1) deep gaps in the housings to permit the bending of wide plates, even wider than the machine itself, (2) a shallow bed, no deeper than floor level, which eliminates all need for special foundations, (3) wider housings, providing extra lateral rigidity and preventing deflections. Under excessive overload, allowable deflections culminate rapidly in the motor before becoming great enough to cause a permanent "set" in the members. A twenty per cent speed loss stops the machine before any damage occurs.

Similar redesigning of the bulldozers made by this company has resulted not only in additional strength, but also in such improvements as a bronze-brushed roller and ram running in ground steel ways.

Heavy coated electrodes are used throughout in the welding of these machines and particular pains are taken to assure welds of the highest quality. Operators are carefully trained and their work thoroughly inspected.

An unforeseen advantage gained through the new type of construction, says this manufacturer, is a decided improvement in appearance. No conscious effort was made along these lines, but the natural consequence of placing motors inside out of harms way, keeping projections and moving shafts away from work and workmen, putting a sturdy crown around eccentrics, and moving fly-wheels from their usual outside positions to safer mountings inside housings, is a handsome machine whose clean lines convey an impression of ample capacity.

Continental Radial Diesel Engines

Use

Light-Weight Welded Crankcases and Bases

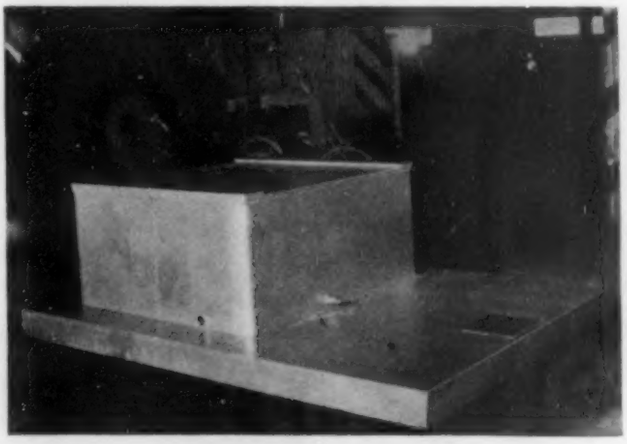
By GEORGE M. GILLEN†

CONTINENTAL Motors Corporation, Detroit, Mich., has developed a 10-cylinder radial two-cycle Diesel engine, developing 450 hp. at 900 r.p.m., for use in rail cars, switching locomotives, power plants and industrial and marine service.

As light weight is essential in the engines, welded steel crankcases, fabricated by our company, are used in their construction. The welded steel crankcases weigh 475 lb. after machining, a weight ratio of slightly more than 1 lb. per hp. The engine itself, complete with all accessories, weighs 3900 lb., a ratio of 8.66 lb. per hp.

The crankcase is fabricated in two halves, the sections being split vertically and bolted together in the engine assembly. Welding was done with covered electrodes under insurance procedure control and the finished structure was thoroughly furnace stress-relieved. All-weld metal specimens deposited with the electrodes used in fabrication showed a yield point of 65,000 lb. per sq. in., ultimate strength of 95,000 lb. per sq. in. and elongation in 2 in. of 24%.

The front half of the crankcase is a welded assembly of plates of high tensile Cromansil steel and S.A.E. 1020 carbon steel. The rear half, which carries a number of bosses, is also a welded assembly of Cromansil steel, S.A.E. 1020 carbon steel and electric furnace steel castings which were used to form the periphery of the cam



Combination Oil Sump and Base

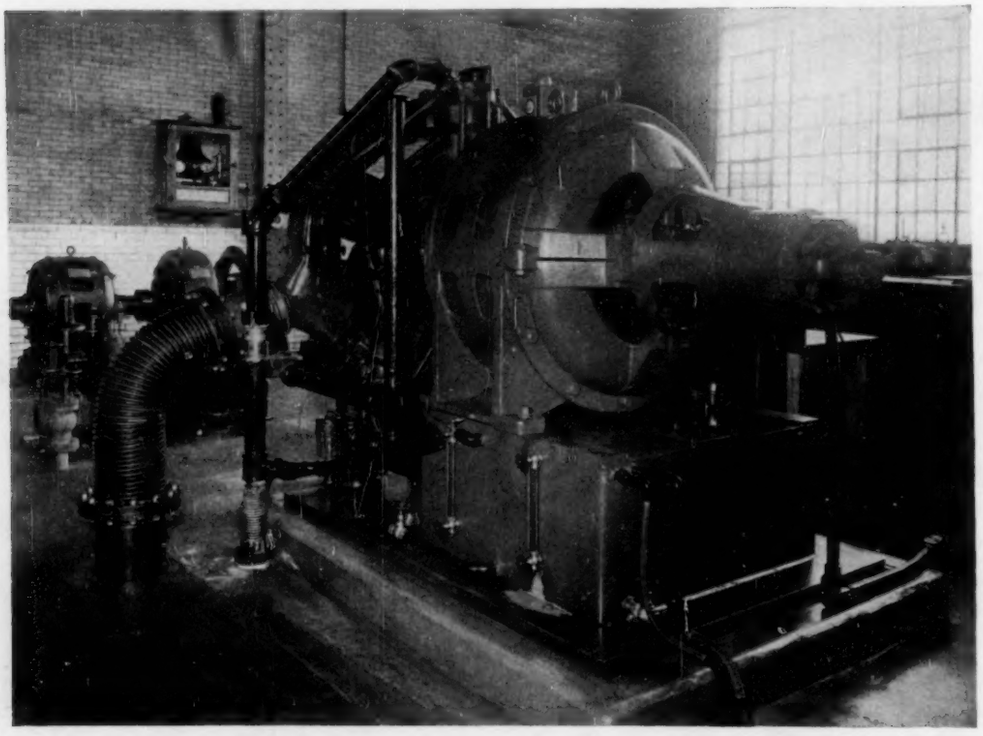
† Sales Promotion, Lukens Steel Company.

pocket due to the intricate contours involved around the push rod guide bushing and the bolts tying the two halves of the crankcase together. The castings were made in units of one per cylinder and the entire assembly welded into one ring which was inspected and machined before welding into the balance of the assembly.

In both sections of the crankcase, high tensile Cromansil steel was used in the main stress members, with carbon steel in parts of secondary importance, as was also the main ring, main web and all the ribs which aid in the transfer of the cylinder stresses to the main web.

to a foundation in order to provide a stable mass. Such an arrangement, however, would be inconvenient in that once the unit is mounted, it would be difficult to unmount it and the entire installation would lose much of its advantage by taking on a high degree of permanency.

The solution for the problem was found in a combined base and oil sump of welded steel construction, which weighs 8240 lb. and in which the sump is welded to a steel plate base 4 in. in thickness. The desired mass was thus obtained and the complete assembly of base, tank,



One of the Continental Radial Diesel Engines with Its Welded Steel Crankcase, Mounted on Its Oil Sump and Base of Welded Steel Construction. The Base Plate Is 4 In. Thick

Welded steel crankcases have been in service in these engines for over one year and have rendered entirely satisfactory performance.

In mounting the radial Diesel engines, it was desirable to have some form of oil reservoir to carry the lubricant to the engine. A conventional method involved mounting the sump on a hollow base, subsequently filling the base with concrete and grouting the entire unit engine and generator is then set down upon a nest of springs, giving a floating mounting and preventing any vibration from reaching the building. The unit remains portable since its mass is movable, and finally, the material used to obtain the mass can be salvaged because the 4-in. plate will have a value any number of years from now and will then still be as good for some other use as it is at the present time.

Pipe Lines Cross Highway

SIGNIFICANTLY, these pipe lines, carrying gasoline and oil (in the raw) come up from Kansas plains to give a future highway's traffic the right-of-way. These sleek-lined arc-welded petroleum carriers, built by the Sinclair Pipe Line Company, will remind passing motorists that this is an era of good looks and efficiency for more than cars, trains and ships.

—A. F. Davis, Vice-President,
The Lincoln Electric Company

Cutting Structural Steel

A Comparative Study of the Effects on the Metal of Cutting by Friction Saw, Shear and Flame with Hand Torch and Machine

By J. H. ZIMMERMAN†

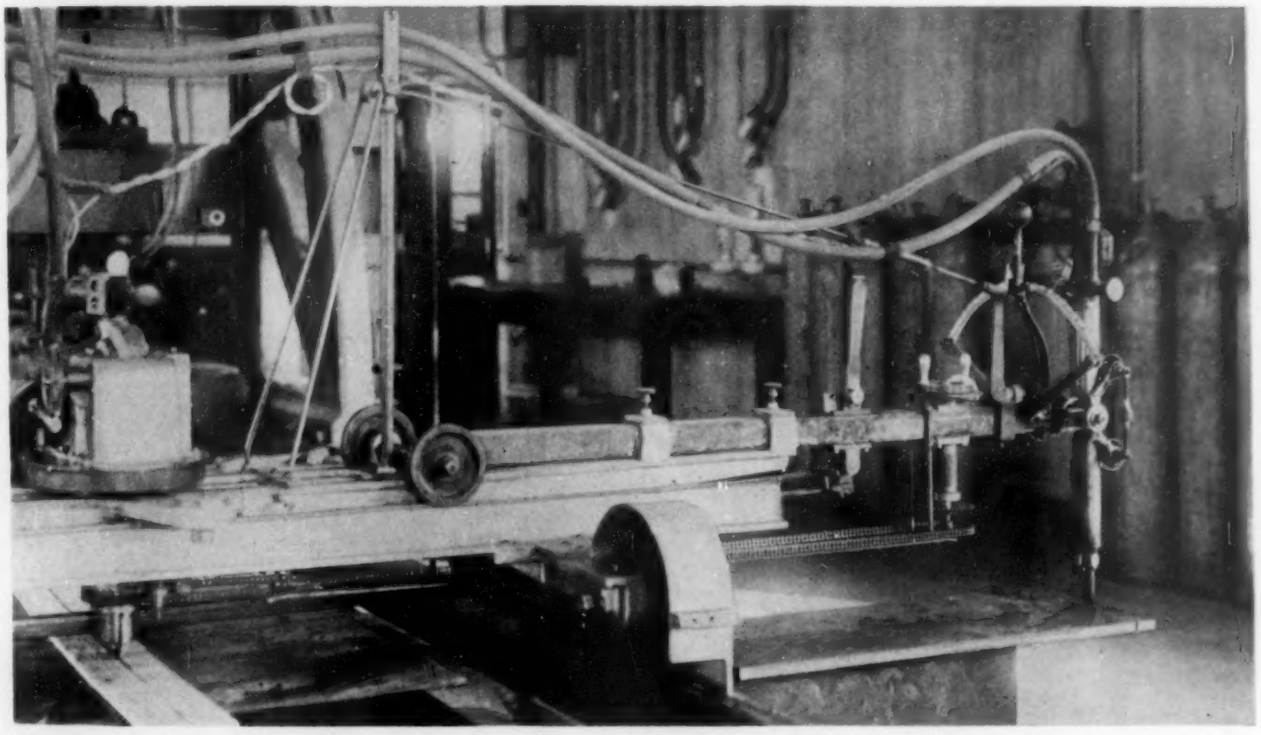


Fig. 1—Preparation of Machine-Flame-Cut Surface

THE purpose of this investigation was to determine as far as possible the effects of several of the more widely used methods of cutting structural steel on the properties of the metal adjacent to the cut surface. It is believed by some that in certain instances the failure of structural members may quite possibly have originated at the cut surfaces through damage caused by the cutting procedure and considerable more or less contradictory information pertaining to this subject has been published. It is hoped that the preliminary work here presented may to a certain extent clarify some of the more controversial issues.

Representative surfaces resulting from the five methods of cutting—machining, shearing, friction sawing, hand-torch cutting and machine flame cutting—are shown in Fig. 2. It should be stated that the machined surfaces were used primarily as a basis for comparison. In each of the four remaining cutting procedures ordinary shop practice was adhered to as closely as possible.

The specimens employed in the comparative study of the cutting methods were all removed from the same $^1/_2$-in. hot-rolled structural-steel plate. Prior to the preparation of the test specimens this plate was carefully inspected and checked for any abnormalities which might contribute toward erratic results. None was found.

Table 1—Properties and Analysis of the Test Plate as Compared with A. S. T M. Specification A9

	Test Plate	Spec. A9
Tensile Properties		
Tensile strength, lb. per sq. in	61,400	60–72,000
Yield point, lb. per sq. in	35,700	30,700
Elongation in 8 in., per cent	30.0	22.8 min.
Cold-bend test, deg. flat	180	180
Chemical Analysis		
Carbon, per cent	0.24	..
Manganese, per cent	0.46	..
Silicon, per cent	0.10	..
Sulphur, per cent	0.033	..
Phosphorus, per cent	0.017	0.06 (max.)

† Massachusetts Institute of Technology.
Cuts loaned through courtesy of "Mechanical Engineering."

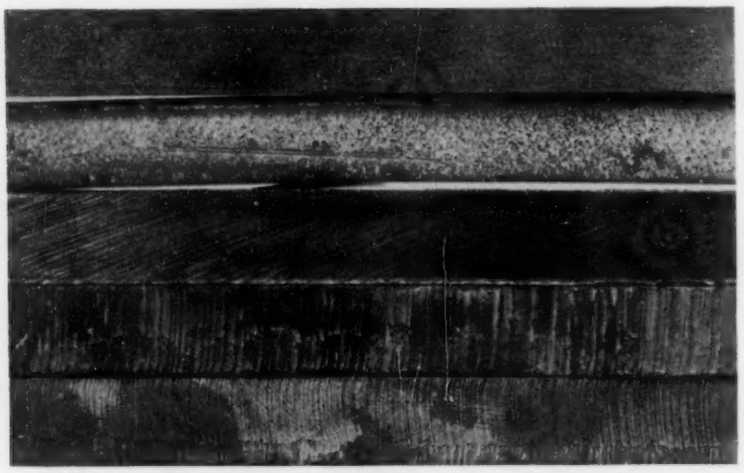


Fig. 2—Appearance of the Surfaces Resulting from the Five Cutting Procedures under Test (from Top to Bottom: Machined, Sheared, Friction Sawed, Hand-Torch Cut and Machine-Flame Cut)

The properties of the plate are given in Table 1 where complete conformity with A. S. T. M. Specification A9[1] is indicated. The slightly banded structure is quite normal for steels of this type and it is believed that no variations in the results to be reported may in any way be attributed to anything other than the cutting procedure involved.

The investigation has been divided into four principal parts, namely, determination of the effect of cutting procedure on: (1) The hardness of the metal adjacent to the cut surface; (2) the microstructure of this metal; (3) the toughness or impact value of the surface metal; and (4) the ductility of the cut surface as measured by the cold-bend test.

Hardness Tests

It is obvious that as far as hardness changes are concerned the principal effects of importance are likely to be confined to the region fairly close to the cut surface. Accordingly, a method of hardness exploration has been applied here that has been used with some success in determining the hardness penetration of nitrided and other case-hardened surfaces. This method consists essentially in preparing a specimen, one surface of which has been treated with the cutting procedure in question, and in the subsequent removal by extremely careful grinding of most of this surface with a taper of 1 in 25. It is possible by this means to measure hardnesses along the tapered surface at such distances between tests as to eliminate any effect of one indentation upon another, but at the same time actually to test the hardness at extremely small increments of penetration from the cut surface. The hardness specimens used for this investigation, together with a sketch indicating the method of preparation of the specimens, are shown in Fig. 3. Throughout the entire investigation of hardness the Vickers hardness-testing machine with a special indexing fixture has been employed. It is believed that the hardness numbers determined with this machine using a 10-kg. load and the $^2/_3$-in. objective are strictly representative of the metal very close to the surface tested, if not at the surface. Readings have been taken at such distances along the tapered surfaces as to permit reporting of the hardness at depth increments of 0.002 in. The results of preliminary tests of the five surfaces indicated that in each case the original plate hardness has been reached before a depth of $^1/_2$ in.

In order more definitely to study conditions immediately adjacent to the cut surface a second series of hardness tests was conducted, the results of which are shown in Figs. 4 and 5. Considerable variation is seen to exist. It will further be noticed that the machined surface which was used primarily as a basis for reference exhibits a slight but quite definite surface hardening. This, however, has completely disappeared at a depth of only 0.002 in. from the surface and is of no significance other than to indicate the sensitivity of the method of testing. The results of all hardness tests are shown in Table 2.

The sheared surface shows a slightly irregular but gradually decreasing hardness for the entire $^1/_2$-in. zone investigated. The phenomenal surface-hardening effect of the friction sawing is extremely interesting, but this effect is seen to disappear, at least for the main part, in the first few thousandths of an inch. The lack of ductility normally accompanying a hardness of this magnitude might be instrumental in the promotion of minute surface cracks through relatively slight plastic deformations of the cut plate. Further consideration of Fig. 5 shows little difference in hardness as brought about by the two flame-cutting methods. In each case there is a certain surface-hardening effect which gradually decreases in a fairly uniform manner until the hardness of the plate stock is reached. A study of Fig. 5 will reveal the relatively mild hardening effects of the flame cutting as compared with the effects of shearing or friction sawing.

Microstructure

The changes in structure as influenced by the various methods of cutting are illustrated in the photomicrographs included in Fig. 4. The plate structure as shown in the case of the machined specimens shows no effect of the machining despite the very thin layer of cold-worked material at the surface. In fact this may be considered to be a perfectly representative photomicrograph of the plate stock used throughout the investigation. The photomicrograph of the sheared surface is representative of the extreme condition, yet this structure showing the tre-

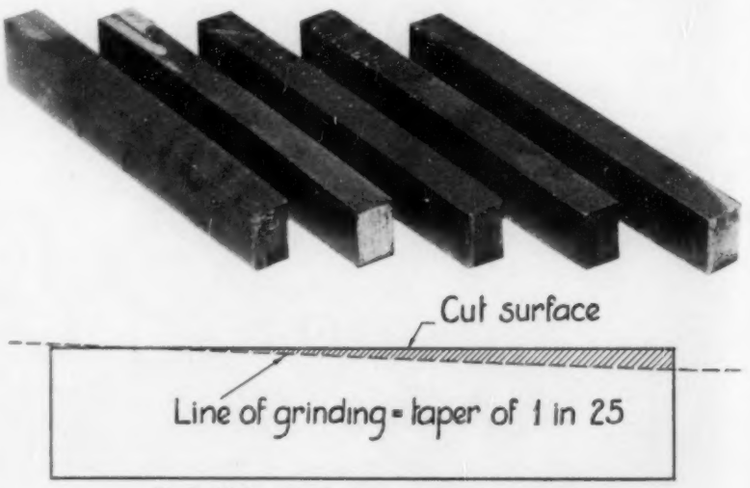


Fig. 3—Hardness Test Specimens and Method of Preparation

[1] American Society for Testing Materials, Standard Specifications for Structural Steel for Buildings.

Table 2—Effect of Cutting on the Hardness of Metal Adjacent to the Cut Surface

Distance from Surface, In.	Vickers Brinell Hardness				
	Machined	Sheared	Friction Sawed	Hand Flame Cut	Machine Flame Cut
0	164	245	345	204	218
0.002	137	240	333	197	206
0.004	137	243	254	197	200
0.006	134	237	246	195	193
0.008	134	237	240	197	190
0.010	134	237	227	200	190
0.012	131	230	198	197	195
0.014	131	242	182	190	195
0.016	134	227	177	197	181
0.018	131	237	174	197	187
0.020	137	233	174	200	185
0.025	134	232	177	174	181
0.030	131	206	171	164	181
0.035	136	200	168	174	173
0.040	133	193	158	170	174
0.045	134	190	151	177	162
0.050	128	189	143	166	163
0.06	131	187	138	181	155
0.07	136	181	133	170	147
0.08	134	173	131	170	157
0.09	134	170	131	164	141
0.10	137	169	136	158	151
0.15	136	159	137	163	147
0.20	136	155	136	157	145
0.25	137	159	134	155	143
0.30	136	153	133	149	143
0.35	138	149	138	141	143
0.40	141	145	136	139	145
0.45	134	141	136	136	141
0.50	138	136	138	139	139
0.60	136	135	138	138	139
0.70	138	138	138	138	137
0.80	136	138	136	136	141
0.90	138	141	143	133	136
1.00	137	138	138	135	138

mendous cold-working effected by the shearing operation is in no sense unusual. The sharp V-notch illustrated is an ideal stress concentrator, although it is unlikely that any crack formation or propagation will result due to the favorable location of the discontinuity with respect to any applied stresses.

The friction-sawed surface discloses a somewhat unusual pseudomorphic structure in the first few thousandths of an inch adjoining the surface. The island-like constituent supported in a ferrite matrix has every appearance of the original pearlitic areas in the region adjacent to the normal structures, yet this arrangement fades into a structure which might easily be confused with that of a thoroughly spheroidized cementite. The extremely rapid self-quenching of the plate edge from a condition of complete or partial solid solubility has left a partially martensitic structure not clearly established by the photograph. The high local hardness of Vickers 345 is the result of the self-quenching action.

The hand-torch-cut surface shows the usual zoning effect with regard to grain size. The coarsened zone accompanying the overheating is, however, restricted to a very narrow band of a few hundredths of an inch after which the extremely fine layer is easily distinguishable. The carbon content of this surface is unquestionably higher than that of the normal plate metal and because of the quenching effects induced by the flow of heat to the adjacent plate metal the resultant structure is largely sorbitic. It is interesting to note the cleavage or Widmanstätten structure in the overheated section immediately adjacent to the flame-cut surface. It will be noted that the same general effects of the hand-torch cutting persist in the case of the machine flame cutting with the exception that the affected zone is confined to a more narrow band. The normal plate structure in this case has been only slightly disturbed at a depth of $^1/_{32}$ in. from the surface and the coarsened region is restricted to a layer of only a few thousandths of an inch in depth.

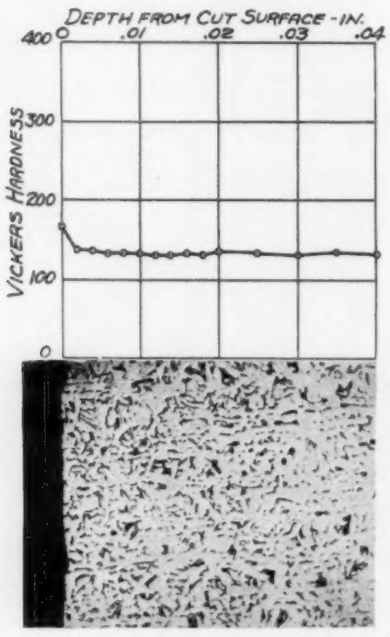
Impact Tests

The specimen used for the impact tests was adopted, not with the idea that it was a perfect criterion of the toughness of the metal adjacent to the cut surface, but with the thought that it would give a fairly comparative measure of the general effect of each of the five cutting procedures on the normal toughness or impact value of the plate material. The transverse-type Charpy specimen employed is not symmetrical as far as cutting effects are concerned. It was necessary to adopt this specimen because of the obvious impossibility of cutting two sides of a specimen less than 0.4 in. square by any of the methods involved other than machining. It is felt that despite this lack of symmetry some effect of the cutting practice should be reflected in the impact resistance of the specimen, and it is apparent from the result shown in Table 3 that this is true.

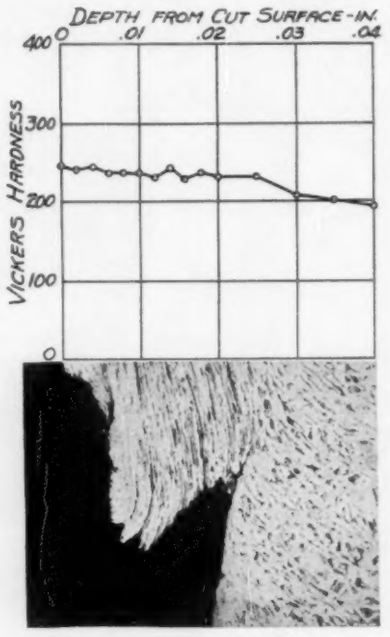
Table 3—Impact-Test Results

Specimen No.	Surface Tested	Notched Surface	Charpy Transverse Impact Value, Ft.-Lb., Individual	Average
1-1	Machined	Any	20.0	21.4
1-2			21.5	
1-2			21.8	
1-4			21.6	
1-5			22.1	
2T-1	Sheared	Top	17.6	17.2
2T-2			16.2	
2T-3			18.4	
2T-4			17.1	
2T-5			16.7	
2B-1	Sheared	Bottom	15.0	16.9
2B-2			17.1	
2B-3			17.1	
2B-4			18.6	
2B-5			16.8	
3-1	Friction sawed	Top	20.3	19.8
3-2			19.5	
3-3			20.0	
3-4			21.0	
3-5			18.4	
4T-1	Hand flame cut	Top	38.8	31.1
4T-2			22.3	
4T-3			39.4	
4T-4			35.4	
4T-5			19.4	
4B-1	Hand flame cut	Bottom	36.5	37.7
4B-2			47.1	
4B-3			22.4	
4B-4			38.9	
4B-5			43.6	
5T-1	Machine flame cut	Top	18.1	20.3
5T-2			21.8	
5T-3			16.4	
5T-4			20.7	
5T-5			24.7	
5B-1	Machine flame cut	Bottom	22.6	21.9
5B-2			22.6	
5B-3			20.7	
5B-4			18.6	
5B-5			24.9	

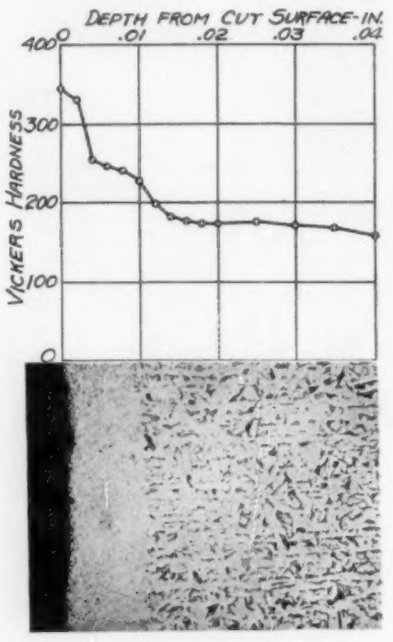
The values obtained for the plate material as machined are perfectly normal with respect to magnitude and uniformity. It will be noted that the average of five individual tests has been used as a basis for comparison in each instance. The sheared specimens show some loss in toughness and the direction of shear is seen to have very little effect on the average impact value. In



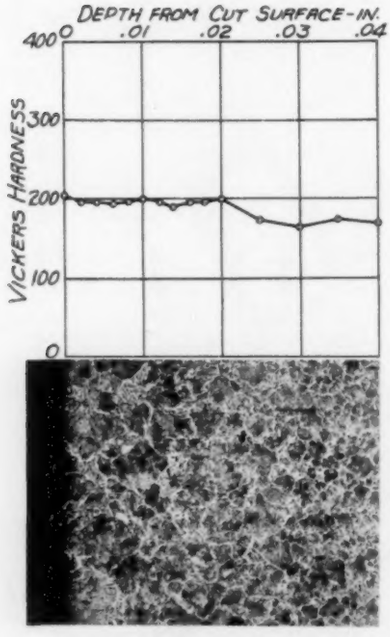
MACHINED SURFACE



SHEARED SURFACE

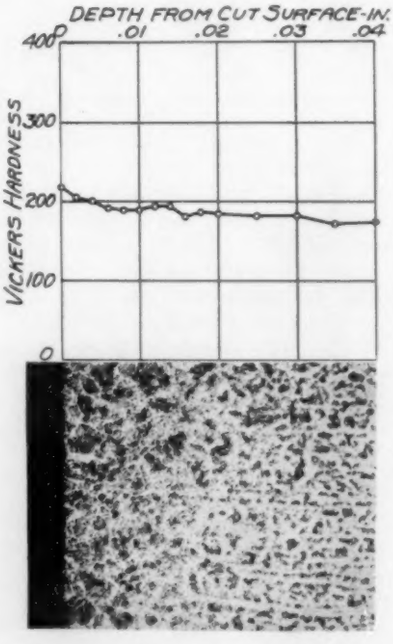


FRICTION SAWED SURFACE



HAND FLAME CUT SURFACE

Fig. 4—Effect of the Five Cutting Procedures on the Surface Hardness and Microstructure of the Test Plate



MACHINE FLAME CUT SURFACE

the case of the friction-sawed specimens there is again a slight drop in toughness. The incongruity between the high hardness for this surface and the small decrease in toughness can be explained by the relatively thin superficial layer of hardened material with respect to the large volume of undisturbed metal. The results for the hand-torch-cut specimens vary between the toughness of the parent plate and twice this same value to give a comparatively high average. The average of the five specimens which were notched at the top of the cut surface show approximately 50 per cent increase over the plate metal and the second series of hand-torch-cut specimens shows an even higher figure. A comparison of the results for the two series of torch-cut specimens shows the metal adjacent to the top or torch side of the cut to be somewhat tougher than the corresponding metal at the bottom side of the cut. This is probably due to the greater heating of the upper surface and the subsequently deeper penetration of the quenching action. The irregularity of these results is unquestionably largely due to the notching effect of the hand-cutting procedure. In the case of the machine-flame-cut specimens very little change in the toughness has been found. The slight decrease from the normal plate value is probably negligible and certainly in no sense serious. Further study of machine-cutting procedure toward the incorporation of some of the toughness inherent in the hand-flame-cut surface is indicated. Again in the case of the machine-flame-cut impact tests, we find the metal at the top surface of the cut plate to be slightly tougher than that at the bottom, presumably because of a slightly greater heating and quenching effect.

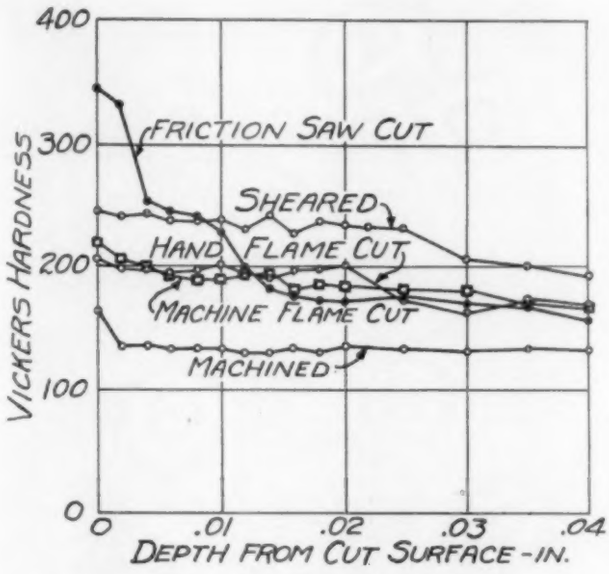


Fig. 5—Composite Chart of the Surface Hardness Effects Induced by the Five Cutting Procedures

Table 4—Results of Cold-Bend Tests

Specimen No.	Type of Cut	Direction of Rolling	Edge of Cut in Tension	Angle of Bend about 1/2-In. Pin	Appearance after Flattening
1-1	Machined	Longitudinal	Either	180	No cracking
1-2		Longitudinal	Either	180	No cracking
1-3		Transverse	Either	180	No cracking
1-4		Transverse	Either	145	Cracked
2-1	Sheared	Longitudinal	Top	95	Cracked
2-2		Longitudinal	Bottom	95	Cracked
2-3		Transverse	Top	60	Cracked
2-4		Transverse	Bottom	55	Cracked
3-1	Friction	Longitudinal	Top	90	Cracked
3-2	sawed	Longitudinal	Bottom	90	Cracked
3-3		Transverse	Top	80	Cracked
3-4		Transverse	Bottom	70	Cracked
4-1	Manual	Longitudinal	Top	180	No cracking
4-2	flame cut	Longitudinal	Bottom	150	Cracked
4-3		Transverse	Top	100	Cracked
4-4		Transverse	Bottom	55	Cracked
5-1	Machine	Longitudinal	Top	180	No cracking
5-2	flame cut	Longitudinal	Bottom	180	No cracking
5-3		Transverse	Top	180	Cracked
5-4		Transverse	Bottom	170	Cracked

Cold-Bend Tests

The cold-bend tests were conducted on specimens cut from the original 1/2-in. plate by the method under test. Two series of specimens were obtained, one with the direction of rolling longitudinal, and the other with the rolling direction transverse. In those cases where the direction of the cutting might possibly influence the cold-bending ductility, a bend in each direction has been made; hence the bend-test results include for each surface four specimens, the results of tests of which are shown in Table 4. The bend tests were conducted in the cold-bend machine by wiping the specimen around a pin 1/2 in. in diameter until appreciable corner cracking had occurred. The corners of these specimens were not rounded as is customary in preparing cold-bend test specimens in order to intensify any effects of the cutting on the ductility of the cut surface. The test results for most specimens are expressed in terms of the angle of bend to produce cracking. The specimens which satisfactorily withstood a bend of 180 deg. around the 1/2-in. pin were subsequently flattened between compression heads. In Fig. 6 are shown the five specimens which satisfactorily withstood complete flattening without cracking.

Summary

The illustrations and tables accompanying this report summarize the findings fairly completely and no attempt will be made to draw rigid conclusions from this preliminary study. In general the tests have shown:

(1) The disturbance of the hardness and structure of the structural-steel plate tested is less severe in flame cutting than in either shearing or friction sawing.

(2) Machine flame cutting does not appreciably affect the toughness of the metal adjacent to the cut surface, hand-torch cutting definitely improves the toughness of this metal, and shearing or friction sawing decreases the toughness slightly.

(3) Ductility of the structural plate tested, as determined by the cold-bend test, is less seriously affected by hand-torch cutting than by either shearing or friction sawing. Machine flame cutting may even be beneficial in this respect.

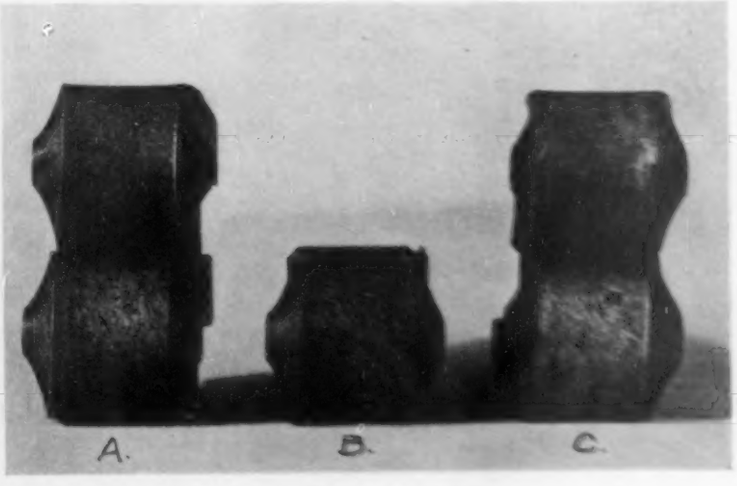


Fig. 6—The Five Cold-Bend Specimens That Satisfactorily Withstood a Bend of 180 Deg. Flat (*A*, Machined, Longitudinal Rolling; *B*, Machined, Transverse Rolling; *C*, Machine-Flame-Cut, Longitudinal Rolling)

CURRENT WELDING LITERATURE

Aircraft Constructional Welding, R. F. Taylor. Sheet Metal Industries (Aug. 1935), vol. 9, no. 100, pp. 522–524.

Alloy Steel. Welding of Special Steels, W. H. Hatfield. Sheet Metal Industries (Aug. 1935), vol. 9, no. 100, pp. 520–521. Methods and types of welding for chromium steels, stainless iron, molybdenum and tungsten steels, and austenitic steels.

Automobile Body Manufacture. Many Welds Make Zephyr. Am. Mach. (Dec. 18, 1935), vol. 79, no. 26, pp. 909–912. Lincoln-Zephyr all-steel body made by novel method; Briggs Manufacturing Co. takes 280 separate pieces of No. 12 and 19 gage sheet steel, weighing 800 lb. and welds them into solid structure; almost 3800 welds of various kinds used to join these pieces; outline of method on basis of illustrations.

Automobile Body Manufacture. Motor-Car Body Welding. Machy. (Lond.), vol. 46, no. 1193 (Aug. 22, 1935), pp. 625–627. Automatic welding operations at plant of Pressed Steel Co. of Great Britain; progress of assembly and welding equipment and practice described.

Automobile Frames. Welding of Chassis Frames, H. S. Bavister. Machy. (Lond.), vol. 46, no. 1189 (July 25, 1935), pp. 520–521.

Boiler Manufacture. Manufacture of Metallic-Arc Fusion-Welded Vessels, C. H. Davy. Machy. (Lond.), vol. 46, no. 1188 (July 18, 1935), pp. 491–492.

Cast Iron *Vs.* Welded Structures, S. Einstein. West. Machy. & Steel World (Apr. 1935), vol. 26, no. 4, pp. 104–106.

Coal Cutters. Bit Life Increased by Use of Hard-Surfacing on Points at St. Ellen Mine, W. Baum. Coal Age (Oct. 1935), vol. 40, no. 10, pp. 411–412 and 426–427.

Copper Alloys. Resistance Welding of Copper Alloys, I. T. Hook. Metal Industry (Lond.), vol. 47, no. 24 (Dec. 13, 1935), pp. 586–590 and 595.

Electric Welding Machines. Improved Control Principle Applied to Arc-Welding Generator, J. H. Blankenbuehler. Boiler Maker & Plate Fabricator (Dec. 1935), vol. 35, no. 12, pp. 349–350.

Electric Welding Machines. New Idea Applied to Arc Welders. Elec. J. (Dec. 1935), vol. 32, no. 12, p. 526.

Electric Welding, Resistance. Control of Electric Resistance Welding, P. W. Townsend. Sheet Metal Industries (July 1935), vol. 9, no. 99, pp. 461–463.

Electric Welding, Resistance. Spot-Welding Practice in France, J. E. Languepin. Sheet Metal Industries (Aug. 1935), vol. 9, no. 100, pp. 517–519.

Industrial Plants. Design and Construction of All-Welded Multiple-Story Steel Structure, R. W. MacBride. Structural Engr., vol. 13 (New series), no. 12 (Dec. 13, 1935), pp. 458–467.

Iron and Steel Plants. Progress of Electric Welding in Steel Industry, H. J. Bowles. Iron & Steel Engr. (May 1935), vol. 12, no. 5, pp. 285–287.

Iron Castings. Bronze Welding or Hard Brazing of Cast Iron and Malleable Iron by Oxyacetylene Process. Int. Acetylene Assn.—Oxyacetylene Committee Publ. sec. 7, 1934–1935, 18 pp. Bronze-welding theory; metallurgy of bronzes; practical bronze welding rods; physical nature of bronze-base metal bond; physical properties of bronze bond; test data; bronze welding practice; adjusting oxyacetylene flame; technique and advantages of bronze surfacing; hand torch bronze welding data; rate of depositing bronze.

Machinery Manufacture. Weight, Machine Parasite, Cut with Low-Alloy Steels, A. F. Clark. Machine Design (Dec. 1935), vol. 7, no. 12, pp. 15–18.

Oxy-Gas Cutting. Flame Cutting...and Its Applications, A. Ussher. Welding Engr. (Nov. 1935), vol. 20, no. 11, pp. 20–25.

Penstocks. Welding a 288-Foot Penstock, K. C. Rowe. Can. Min. J. (Oct. 1935), vol. 56, no. 10, pp. 479–480.

Petroleum Gas, Liquefied. Propane and Butane as Industrial Fuels, E. A. Jamison and W. H. Bateman. Iron & Steel Engr. (Apr. 1935), vol. 12, no. 4, pp. 209–213 and (discussion), 213–214.

Pipe Lines. Sample Pipe Welding Specifications. Int. Acetylene Assn.—Oxyacetylene Committee Publ. sec. 5, 7 pp. Specifications for heating, plumbing, refrigeration, air conditioning and process piping installations for pressures not to exceed 100 lb. per sq. in. and temperature not to exceed 406° F. and specifications for power, refrigeration, air conditioning and process piping installations for pressures exceeding 100 lb. per sq. in.

Properties. Prediction of Behavior for Welded Construction, N. F. Ward. West. Machy. & Steel World (July 1935), vol. 26, no. 7, pp. 205–207.

Sheet Metal Industry. Resistance Welding Methods in Sheet Metal Industry, L. B. Hunt and C. F. Davidson. Sheet Metal Industries (July 1935), vol. 9, no. 99, pp. 459–460. Seam welding and special purpose seam-welding machine; wear on electrode rollers; application of projection welding which is formation of number of spot welds in one operation. (Concluded)

Structural Steel. Relative Rigidity of Welded and Riveted Connections, C. R. Young and K. B. Jackson. Can. Engr. (Apr. 23, 1935), vol. 68, no. 17, pp. 17–18.

Welded Steel Structures. Studies Throw Light on Thermal Effect of Welding Structural Steel, W. M. Wilson and R. L. Brown. Ry. Age (Dec. 21, 1935), vol. 99, no. 25, pp. 816–818. Tests, conducted at Materials Research Laboratory of University of Illinois, indicate presence of high stresses but show that efficiency of metal added is not seriously affected; investigation was concerned with Girard viaduct, steel structure, 1500 ft. long of tower and girder-span type.

Tests for Selection of Operators of Welding Equipment (Tentative). Int. Acetylene Assn.—Oxyacetylene Committee Publ. sec. 6, 1934–1935, 18 pp.

Training. Qualification Tests for Pipe Welders, R. B. Lincoln. Welding Engr. (Nov. 1935), vol. 20, no. 11, pp. 28–30.

Training. Technical Training of Welders, D. H. Ingall and D. D. Stockley. Sheet Metal Industries (Sept. 1935), vol. 9, no. 101, pp. 586–588.

Welding Rods. Improved Methods of Fabricating 18-8 Chromium Steels, O. C. Jones. Boiler Maker & Plate Fabricator (Dec. 1935), vol. 35, no. 12, pp. 334–336 and 339.

Welding Rods. Columbium in Welding Rods for Stainless Steels, W. J. Priestley. Metal Progress (Dec. 1935), vol. 28, no. 6, pp. 56–58.

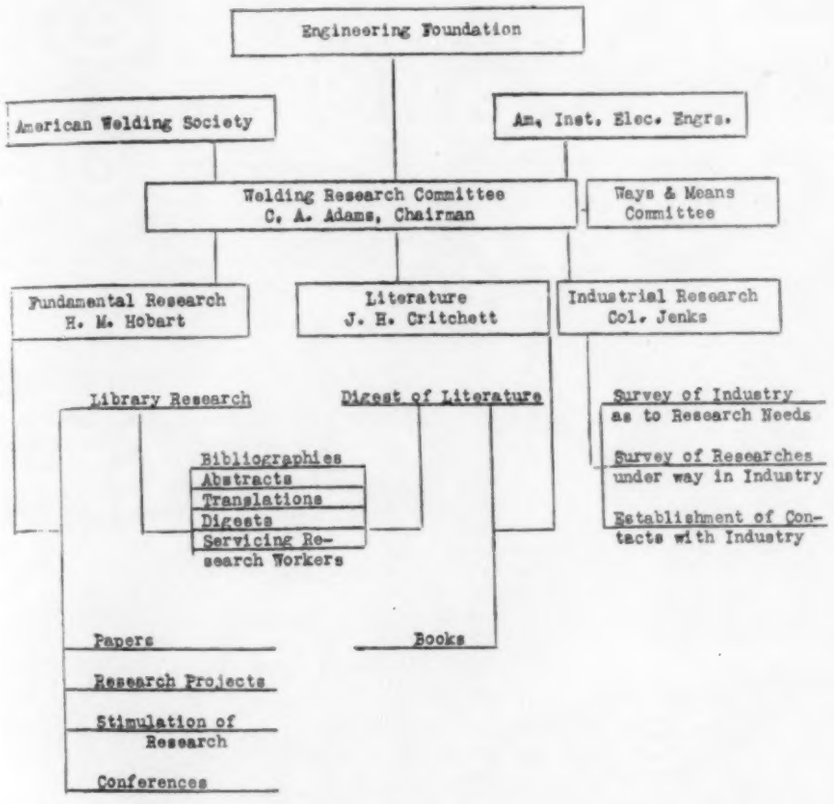
1935 BOUND VOLUME

Bound Volumes of the JOURNAL of the Society for the year 1935 are now available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Also contains Subject and Authors' Index. Price, $5.00 plus postage to members; $6.50 to non-members.

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

Engineering Foundation Research Committee

In the last issue of the JOURNAL there is given a brief description of the present and contemplated activities of the newly organized Welding Research Committee of Engineering Foundation. Below there is given an organization chart of this Committee's activities, which is being jointly sponsored by the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineers.



Pamphlets

The Lukens Steel Company of Coatesville, Pa., has just issued an attractive bulletin on "Methods for the Fabrication of Nickel-Clad Steel." The pamphlet of twelve pages is copiously illustrated with sketches and photographs.

Welding in Europe

Mr. H. W. Roth, President, Roth Welding Engineering Company, who has recently returned from a visit abroad, advises us that resistance welding in the automotive industry is not as far advanced as in this country. He attributes this to the fact that mass production has not been possible in Europe to the same extent as in the United States. However, he states that some of the standard resistance welding machines as, for instance, the automatic Spot Welders and Flash Welders are highly developed for a more universal application as a machine tool. Huge Flash Welders for welding solid round or square stock up to 40 square inches in cross section, equipped with full automatic push-button control, have been developed in Germany, and are in use for production and repair work.

In the field of Electrical Arc Welding, use of fabricated steel parts for the manufacturing of machine tools and general steel construction has increased enormously, especially in Germany, due to forced economy in the use of raw materials.

He also states that welding of light gage metal with A.C. arc welders is widely used in Germany.

A. S. T. M. Meeting

The 1936 Regional Meeting will be held Wednesday, March 4th, at Hotel William Penn, Pittsburgh.

At the regional meeting, a Symposium on High-Strength Constructional Metals will be held. This comprises five papers dealing with alloys of copper, aluminum and magnesium alloys, nickel and its alloys, carbon and low-alloy steels and corrosion-resisting steels.

Welding Interests Other Organizations

At the Annual Meeting of the A. S. C. E. held in New York, January 16th, Mr. W. Spraragen, Technical Secretary of the Society, presented a paper on "Welding—An Important Construction Tool." About four hundred members of this Society attended this meeting. Mr. Spraragen stressed the recent developments in welding which resulted in increasing the tensile strength from 40,000 and 50,000 pounds to 65,000 and 75,000; Izod values 5 foot-pounds to 50; endurance limit from 10,000 to 28,000 with corresponding increases in ductility and other physical properties. 100,000 pounds per square inch tensile strength was possible in special steels.

The other national meeting was that of the Society for Automotive Engineers in Detroit. One session was arranged as a joint session with the Detroit Section of the A. W. S. on January 17th. Mr. C. L. Eksergian, Regional Vice-President, presided and Mr. M. Hayes, Chairman, and Mr. J. D. Tebben, Vice-Chairman of the Detroit Section, cooperated in making arrangements. The following speakers presented papers: Dr. F. R. Hensel, Consulting Engineer, talked on "The Physical Chemistry of Arc Welding"; Mr. E. I. Larsen, Research Engineer, spoke on "The Fundamentals of Spot Welding."

Translations

As indicated in the January issue of the JOURNAL we are trying to make available translations of important articles in the foreign press. A small supply of the translation "Progress in the Technique of Welding in the First Half of 1934" (a review by Wm. Lohmann published in *Stahl und Eisen*), has been furnished through the courtesy of one of the cooperating companies. Copies will be furnished upon request as long as the supply lasts.

United States Civil Service Examinations

1. Senior Inspector, Engineering Materials (Mechanical), $2600 a year
2. Senior Inspector, Engineering Materials (Electrical), $2600 a year
3. Senior Inspector, Aircraft Overhaul and Repair (for filling position of Senior Inspector, Engineering Materials, Aeronautical), $2600 a year
4. Inspector, Aircraft Overhaul and Repair (for filling position of Inspector, Engineering Materials, Aeronautical), $2000 a year
5. Inspector, Engineering Materials (Mechanical), $2000 a year
6. Inspector, Engineering Materials (Electrical), $2000 a year
7. Inspector, Engineering Materials and Construction (Aeronautical), $2000 a year
8. Inspector, Engineering Materials (Aeronautical), (for Aeronautical Engineering Materials, General, and Aeronautical Engineering Materials, Motors), $2000 a year

Applications must be on file with the United States Civil Service Commission at Washington, D. C., not later than February 24, 1936.

Prediction of Weld Performance

Professor N. F. Ward has called attention to an error which appears in the article on the above subject, Vol. XIV, No. 12, December 1935, page 11. The correct form of the model equation should read:

$$= m \frac{E_p \times p \text{ of prototype}}{E_m \times p \text{ of model}}$$

or: Stress in prototype/Stress in model

$$= n^2 \times \frac{E_p \times p_p}{E_m \times p_m}$$

Specification for Carbide of Calcium

The British Standards Association has issued a new Specification for Carbide of Calcium. This specification is now in force and comprises, together with the actual specification for graded sizes, an Appendix A, setting out methods of tests and analysis, and Appendix B, embodying the conditions of sale and purchase.

Urges Wider Use of Steel Construction for Permanent Dams

Members of the Metropolitan Section of the American Society of Civil Engineers and AMERICAN WELDING SOCIETY were urged to develop wider use of steel frame construction for large dams by Dr. Otis E. Hovey, consulting engineer and national authority on steel structures, at a meeting held at the Engineering Societies Building, 33 West 39th Street, February 4th.

Safety, accuracy of load resistance measurements, constant inspection during all processes of manufacture and construction, and economy, were cited by Dr. Hovey as being among the factors in favor of the use of steel frame construction for permanent dams.

"Loads on dams are the most definite of any with which the civil engineer has to deal," Dr. Hovey declared.

"Steel," Dr. Hovey added, " is made and rolled at the mills and fabricated at the shops under full control. There is no uncertainty concerning the uniform quality of the material or in its application in the structure. A steel frame dam can be designed so that its principal members resist the water pressure in the most direct manner and with no uncertainty as to their action. The loads on the foundations are definite. Consistent factors of safety against overturning and sliding can be maintained.

"Steel dams are made water-tight," Dr. Hovey explained, "by the old process of riveting and calking, or by the application of the more modern methods of fusion welding. These methods apply equally to steel frame dams or steel faced dams.

Asserting that steel frame dams are more economical to construct than other types, Dr. Hovey added: "Estimates were made of the cost of construction of a steel frame dam in place of a concrete dam, 165 feet long with a maximum height of 54 feet, which was constructed across the Saranac River in 1913. The estimated cost of the steel dam was found to be 29 per cent lower."

SECTION ACTIVITIES

BOSTON

Mr. C. H. Jennings of the Research Laboratories, Westinghouse Electric & Mfg. Co., spoke to this Section at its regular meeting on December 20th. A large group heard Mr. Jennings tell about "Welding Problems on Large Structures." Slides and blackboard sketches were effectively used to illustrate the several problems, and solutions discussed at the meeting.

On January 17th, Dr. J. C. Hodge, Chief Metallurgist of the Babcock & Wilcox Co., spoke to the Section on "Fundamentals of Good Welding." Many slides were shown during his talk. Results of studies and tests of welds using bare and coated electrodes, and of welds using long and short arcs were included in Dr. Hodge's interesting talk. Electric welding only was considered at this meeting.

The Section will hold its next meeting on Friday, February 28th, in Room 5-330, Massachusetts Institute of Technology. Mr. J. H. Critchett, Vice-President of the Union Carbide and Carbon Research Laboratories, will be the speaker. The meeting is scheduled to start at 7:30 P.M.

CHICAGO

The regular monthly meeting of the Chicago Section was held on January 24th, at the Mission Hall, Armour Institute of Technology, which will be the regular meeting place of all future meetings. Mr. Albert Reichmann, Vice-President of the American Bridge Company, presided as chairman. The subject of the meeting was "Automatic Welding by Metallic Arc, Carbon Arc and Gas Processes." The program was as follows: From 7 to 7:30 P.M. a Lecture Course on "Metallurgy as Applied to Welding," by Jules Muller, Chicago Steel and Wire Co.; from 8 to 9:30 P.M. "Automatic Welding by the Metallic Arc, Carbon Arc and Oxyacetylene Processes." Mr. A. M. Candy, Consulting Engineer, Hollup Corp., Mr. O. A. Bailey, Chief Engineer, Chicago Bridge Iron Works, spoke on the above subject. Mr. N. G. Copely, Norge Corporation, spoke on "Automatic Gas Welding."

CLEVELAND

The third regular monthly meeting of the Cleveland Section held on January 27th at the Cleveland Engineering Society, 410 Hanna Building, was on the subject "High Pressure Piping." The speaker of the evening was Mr. J. A. Freiday, Mechanical Engineer, Thos. J. Murray, Inc. The talk was illustrated and proved very interesting to all present.

MARYLAND

Mr. E. W. P. Smith, Consulting Engineer of the Lincoln Electric Company, gave a talk at the January 22nd meeting of this Section, on "Practical Welding Problems Demonstrated by Means of the Polariscope."

MILWAUKEE

The January meeting of this Section was held on the 10th at the Milwaukee School of Engineering. Mr. E. L. Quinn, of the American Manganese Steel Corp., presented an address on "Procedure on Manganese Steel Welding." Mr. Whitmer, Welding Engineer of the Republic Steel Corp., spoke on "Welding of Stainless and Low Alloy Steels."

PHILADELPHIA

The February meeting of this Section will be held on the 17th. Mr. J. A. Mitchell, Manager of Production, Belmont Iron Works, will speak on the subject "Welding in a Structural Steel Plant." Members of the American Society of Civil Engineers are cordially invited to attend this meeting.

PITTSBURGH

The next regular meeting of the Pittsburgh Section will be held February 19th, in the East Room of the Roosevelt Hotel. Mr. E. W. Forker, Manager of the Process Equipment Division of the Blaw-Knox Company, will present a paper on "Welding of Process Equipment." Mr. Forker's talk will cover welding of Everdur, stainless steels and various alloys. His talk will be illustrated with slides.

SAN FRANCISCO

The January meeting of this Section was held on the 31st. An exceptionally interesting program was arranged by the program committee. Mr. Jean La Force, Mgr. Process Service, Linde Air Products Company, presented the paper on "The Permanence of Oxyacetylene Welding." Mr. C. O. Mansur of the Eccles and Davies Machinery Company of Los Angeles, spoke on the subject "Electric Welding of Copper Brass and Bronze."